

PROCEEDINGS
OF THE
ROYAL SOCIETY OF EDINBURGH.

VOL. VIII.

1873-74.

No. 88.

NINETY-FIRST SESSION.

Monday, 2d February 1874.

Professor Sir WILLIAM THOMSON, President,
in the Chair.

The following Obituary Notices of Deceased Fellows of
the Society were read:—

1. Biographical Notice of J. S. Mill. By Professor Fraser.

John Stuart Mill was born in London on the 20th of May 1806, and died at Avignon on the 8th of May 1873. He was of Scotch descent. He was connected with Edinburgh not only as having been an honorary member of this Society, but because his father, James Mill, the historian of British India, and author of the "Analysis of the Human Mind," received his academical education here. His grandfather was a small farmer, at Northwater Bridge, in the county of Angus, of whom I find nothing more recorded. The father, by his extraordinary intellectual promise when a boy, drew the attention of Sir John Stuart, then member for Kincardineshire, by whom he was sent to the University of Edinburgh, at the expense of a fund, established by Lady Jane Stuart and some other ladies, for educating young men for the Church of Scotland. Towards the end of last century, James Mill attended the classes in Arts and Divinity. He was a pupil of Dalziel, the Professor of Greek, whose prelections he attended, I believe, for three sessions, and his philosophical powers were called forth by Dugald Stewart's

lectures in Moral Philosophy. I do not know by what Presbytery he was licensed to preach, but I have heard Sir David Brewster say that he had listened to one of his sermons. When a student at the University it seems that he was given to reading books of a sceptical tendency in religion. He soon found the ministry uncongenial to him, having satisfied himself that he could not believe the doctrines of any Christian Church.

About the year 1800 James Mill removed to London, where for nearly twenty years he made his living by his pen. He was a man of singular force of character and subtlety of intellect—a stern Scotch Stoic or Cynic, with an Epicurean creed. He married soon after he settled in the metropolis, with only the precarious income of a literary adventurer. The eldest son of his large family was John Stuart Mill. He was born about the time the “History of India” was begun. In the twelve following years the extraordinary energy of the father was chiefly given to this great work, and to the instruction of his eldest son.

That eldest son has himself described in his “Autobiography” some of the original influences by which his own mind and character were formed. The stern paternal schoolmaster was one of the most important. The story of young Mill’s early instruction is as extraordinary as any in the records of English training. Books in Greek, Latin, and English; in history, logic, and analytical psychology, were among the means—the end being the production of as perfect a reasoning machine as could be produced out of the boy. What is commonly included in the higher education began with him in childhood. He was introduced to Greek when he was three years of age. Before he was eight he had read many Greek books, including the *Theætetus* of Plato. He had also read a great deal of history, including Hume and Gibbon, and had discussed what he had read with his father, in their rural walks about Newington Green, where the Mills were living from 1810 to the end of 1813. In the winter of 1813 they moved into a house, rented from their friend Jeremy Bentham, in Queen Square, Westminster. About the time this change was made young Mill began to learn Latin. Before he was twelve he had read most of the Latin and Greek poets, historians, and orators, much of the *Rhetoric* of Aristotle, and a great deal of ancient history. At twelve his philosophical

education began. He studied logic in the *Organon*, in Latin treatises of scholastic logic, and in Hobbes. His later experience made him set great value on this early familiarity with Aristotelian logic. The first intellectual operation in which he arrived at proficiency was dissecting bad arguments, and finding in what the fallacy lay. Ricardo and a course of political economy followed; also much study of Plato. The high expectations his stern and exacting preceptor had of him at this time appear in a letter from James Mill to Jeremy Bentham in 1812.

In May 1820 he was sent to France. His father had in the year before been appointed one of the Assistants of the Examiner of Correspondence in the India House. Abroad the boy lived in the family of Sir Samuel Bentham, a brother of Jeremy. He was introduced to M. Say, the political economist, and other French *savans* in Paris. This was the beginning of the intimate sympathy with the literary and political society of France, which was always characteristic of John Mill.

In July 1821 he returned to England. He resumed his old studies, with the addition of some new ones. He read Condillac "as much for warning as example." In the winter of 1821-22, he studied jurisprudence under John Austin, and also in the writings of his father's friend, Jeremy Bentham. His whole previous education had been in a certain sense a course of Benthamism, for he had been always taught to apply Bentham's standard of "the greatest happiness." He lived much in Bentham's society, and often accompanied him and his father in their walks together, at Newington Green and afterwards in Westminster, besides making long summer visits to him at Ford Abbey, in Devonshire. Before he was fifteen, his studies were carried into analytic psychology, still under his father's direction. He read Locke, Berkeley, Helvetius, Hartley, Hume, Reid, Stewart, and Brown on "Cause and Effect." The elder Mill about this time began to write his "Analysis of the Human Mind," which was published seven years later, in 1829, and the son was allowed to read the manuscript, portion by portion, as it advanced.

This training, while it produced an astonishing precocity of logical intelligence, was not equally favourable to physical vigour, and practical skill or sagacity. Mr Mill tells us that as he had

no boy companions, and the animal need of physical action was satisfied by walking, his amusements, which were mostly solitary, were in general of a quiet if not bookish turn, and gave little stimulus to any other kind of mental acting than that which was already called forth by his studies. He consequently remained long, and in a less degree always remained, inexpert in everything requiring manual dexterity, and his mind as well as his hands did its work lamely, when it was applied to the practical details which are the chief interest of life to the majority of men. He was constantly meriting reproof by inattention, inobservance, and general slackness of mind in matters of daily life.

Beauchamp's "Analysis of the Influence of Natural Religion on the Temporal Happiness of Mankind" (papers of Bentham edited by Grote) was read by young Mill. This was an examination not of the truth, but of the usefulness of religion, and suited his mental condition well. His father had educated him from the first without any religious belief. The elder Mill, "finding no halting-place in Deism, had yielded to the conviction that nothing whatever can be known concerning the origin of things." He impressed upon his son from the first that the manner in which the universe came into existence was a matter on which nothing was or could be discovered; that the question, "Who made me?" cannot be answered, because we can have no experience from which to answer it; and that any answer only throws the difficulty a step further back, since the question immediately presents itself, "Who made God?" He assumed it to be impossible that a world so full of evil could be the production of a cause combining infinite power with perfect goodness. John Mill was thus, he says himself, "one of the very few examples in this country of one who has not thrown off religious belief, but who has never had any." He looked upon the modern exactly as he did upon the ancient religion, as something which in no way concerned him. If a philosopher has to comprehend what exists, it was unfortunate for Mr Mill, and unfavourable to the comprehensiveness of his philosophy, that he should have thus been trained to overlook Christianity, the greatest fact in European life.

Other than home influences now began to have play. In May 1829 his professional occupation was determined. He became a

subordinate in the India House under his father, who was resolved not to leave him to the uncertainty of the adventurous literary life. Steady official duties in Leadenhall Street occupied him in the thirty-five following years, at the end of which the East India Company was extinguished as a governing power. But his duties there always allowed him to have time enough for study.

He was now introduced gradually to a wider companionship. In the winter of 1822-23, he had formed the plan of a little society, composed of young men acknowledging Utility as the standard in ethical and political thought. At his suggestion it was called the Utilitarian Society. It was the first time that any one had taken the title of Utilitarian; but the term soon made its way into the English language. John Austin, William Ellis, John Arthur Roebuck, George Grote, and others, appear among his friends and associates.

He began about this time to show himself in print. His first published writings were two letters, which appeared in the end of 1822, in the "Traveller" newspaper, in defence of some opinion of Ricardo and his father in political economy. Early in the following year he published some letters in the "Morning Chronicle," in favour of complete freedom of religious discussion, in connection with the trial of Richard Carlile for blasphemy. During 1823 several of his writings appeared in the "Traveller" and "Morning Chronicle."

In April 1824 the "Westminster Review" was started, under the auspices of Jeremy Bentham, with John Bowring as editor. From that time till July 1828 Mr Mill was its most frequent contributor. He wrote thirteen articles in these years. One is especially worthy of note,—a review of Whately's "Logic," which appeared in January 1828, which it is interesting to compare with the modification and extension of the science proposed fifteen years afterwards in his own System. In 1827, at Bentham's request, his name was given to the world as editor of that philosopher's greatest treatise, the "Rationale of Evidence," the preface to which was written by Mr Mill: his previous publications were anonymous. This work, and the annotations, occupied much of his time for about a year. The connection of the subject with the form which logic afterwards took in his own hands is manifest.

In these years various influences helped to show that he had a nature too deep and human to be satisfied with the hard Benthamite creed in which he was trained. For some years after 1828 he wrote little, and nothing regularly, for publication. He congratulates himself on this. If he had gone on writing, it would have disturbed, he thinks, an important transformation in his opinions and character which was taking place about this time. For years his one object in life had been to be a reformer of society. He was now awakened from this as from a dream. All his happiness was to have been found in the steady pursuit of this end: the end, he found, had ceased to charm him, and he seemed to himself to have nothing left to live for. He was weighed down by melancholy. Part of the explanation probably was that his nerves were exhausted by an early life too purely intellectual. His condition so far reminds one of the account which David Hume gives of himself in the very curious letter to a physician, written at a corresponding period of life, and preserved among the papers in the possession of this Society, published by Mr Burton in his "Life of David Hume." It is interesting to compare Hume's story, in that letter, and Mr Mill's in his "Autobiography." The health of both seems to have been broken for the time by a too ardent application to abstract studies. The truth, however, was that Mill had discovered in some degree the narrowness of the theory of life on which his early training had been based. It had left him nothing worth living for. Mill, like Hume, gradually recovered, but with a more marked change in his mental tone and opinions afterwards than one finds in Hume. His early Utilitarianism was modified. While still convinced that happiness was the chief end of human life, he now, with doubtful consistency, thought that this was to be attained by not making it the direct end; and that those only are happy who have their minds fixed on some object other than their own happiness—the philanthropic improvement of mankind, for instance. He found, too, that the emotions needed to be cultivated as well as the intellect. He began to feel the importance of poetry and art, especially music, as instruments of human culture. He was always very fond of music, and a scientific proficient.

The reading of Wordsworth for the first time, in the autumn of

1828, was an important event in Mr Mill's life. Beauty in nature had a power over him then that was a foundation for his taking pleasure in Wordsworth's poetry. He became a Wordsworthian, and contended on this side against Roebuck in a Debating Society. His sympathies were carrying him more and more away from Benthamism, and towards a deeper and truer philosophy of life. He was brought into friendly companionship with Frederick Maurice, and John Sterling, and other admirers of Coleridge. He became one of Coleridge's occasional visitors at Highgate, to whom I have heard that he was introduced by Sir Henry Taylor. After 1829 he withdrew from the Debating Society, and pursued his studies and meditations in private, endeavouring thus to adjust the relation of his new ideas and sympathies to his old opinions. Indeed, after this he seems to have lost his early fondness for Societies for discussion: a few years ago he declined to connect himself with the lately-founded Metaphysical Society of London, having the opinion that valuable results in subjects of abstract philosophy are best attained in solitary dialectic, or with a single interlocutor.

In the Society from which he withdrew, logical questions had been often discussed. About 1830 he began to put on paper thoughts on the theory of logic, and especially on the relations of induction to syllogism. Thus his own system of logic began to take shape. In political philosophy, too, he began to see that the truth was something more complex and many-sided than his early instruction had presupposed. This tendency was encouraged by a sympathetic study of the writings of the St Simonian school in France, and of the early works of Auguste Comte. Thomas Carlyle, too, had an effect upon him. He felt himself at an increasing distance from his father's whole tone of thought and feeling.

The year 1830, above all, was the commencement of what he considered the most valuable friendship of his life—that of Mrs Taylor, who, twenty years afterwards, became his wife, and whose influence over him, for good or evil, marked the whole remainder of his course.

About 1832 and the two or three following years of political excitement, he published writings in the "Examiner" and other

newspapers, and in the "Monthly Repository," which were more according to his matured judgment than his previous periodical essays.

His father died in June 1836. This seems to have freed him from some restraints and reticences. His friend Sir William Molesworth, a political and metaphysical thinker, had proposed to found a new Review, provided Mr Mill would agree to conduct it. In this way he was editor of the "London"—latterly the "London and Westminster—Review" in the years between 1835 and 1840. This Review was the organ which he then used for the spread of his opinions. It enabled him to express in print the results of his altered modes of thought, and to separate himself in a marked manner from the narrower Benthamism of his early writings. He resigned the editorship in 1840, after which he usually preferred for his essays the wider circulation of the "Edinburgh Review."

The first use Mr Mill made of the leisure gained by freedom from the cares of a brilliant editorship was to resume his "Logic." The preparation of this historically important treatise had occupied him at intervals for twelve years. In 1841 it was ready for the press, but circumstances delayed the publication till the spring of 1843. He now appeared for the first time as the author of a book, and of his greatest book—"A System of Logic, Ratiocinative and Inductive, being a Connected View of the Principles of Evidence and the Methods of Scientific Investigation." It is the most elaborate treatise in the English language on the logical procedure in Induction. Since the publication of the "Novum Organum" and the "Essay on Human Understanding," no such comprehensive attempt in logical theory and the principles of the formation of knowledge had been made by an Englishman. Mr Mill had not forgotten his early studies in Aristotelian logic, which, in his correlation of induction and syllogism, he tried to assimilate with the methods of modern science. If we do not accept the result as satisfactory, we may at any rate allow that it has usefully called attention to the one-sidedness of merely formal logic. If he fails to show that all inference is ultimately from observed particulars to unobserved particulars, without any need for general notions, he has at least helped to prove the fruitlessness of merely verbal

sylogising, and to show the part which facts have in all our actual reasonings. It is as a logician probably that Mr Mill will be longest remembered in the history of English and European thought, and as having connected the revived logical studies of this country with the spirit and procedure of modern experimental science.

The same decade which gave birth to Mr Mill's "Logic" saw the first publication of the other great treatise of his life—next in importance to his "Logic." In 1848 his "Principles of Political Economy, with some of their Applications to Social Philosophy," were given to the world. Through this book he became to the nineteenth century in some degree what Adam Smith had been to the eighteenth by his "Wealth of Nations." It had been heralded in 1844 by "Five Essays on some Unsettled Questions in Economic Science." The "Political Economy" showed a return in some particulars from his previous extreme of reaction against his early Benthamism, along with a disposition to sceptical criticism of many of the presuppositions of the older school of political economists. His ideas of ultimate social improvement were becoming more revolutionary. His view of private property was becoming modified, and especially of the rights of individuals to land. Co-operation and Socialism began to take the place of Competition and Democracy in his thoughts.

The "System of Logic" and the "Principles of Political Economy" are the two books round one or the other of which almost all that Mr Mill has ever written may be said to circulate. The one describes his view of the intellectual means; the other is connected with the aim or end of the whole labour of his manhood. The logical employment of intellect for the improvement of society was in brief his life. Eight editions of the "Logic" have now been published; the "Political Economy," after passing through seven editions, was issued in a cheap form in 1865.

The ten years which followed the publication of the "Political Economy" formed a long pause in Mr Mill's course as an author. He was married to Mrs Taylor in April 1851, her former husband having died two years before. They lived in extreme seclusion for some years, withdrawn even from the society of his intimate friends, and under influences which tended again to confine his

sympathies. The silence was broken only by an occasional article in the "*Edinburgh Review*," or by replies to criticisms on one or other of his two great books.

Changes now occurred. In 1856 he was made Examiner of Indian Correspondence, and thus placed at the head of the office in the India House, in which he had served for thirty-three years. In the following year the Government of India was transferred from the Company to the Crown; after an unavailing remonstrance, drafted by Mr Mill, in the name of the Court of Directors, which was pronounced by Lord Grey the ablest State paper he had ever read. He afterwards declined an invitation by the present Lord Derby, then Indian Secretary, to form one of the newly-constituted Board of Indian Council.

Mr Mill had arranged to spend the winter of 1858-59—the first after his retirement from office—in the south of Europe. The death of his wife at Avignon, on their journey, frustrated his plans and hopes. The profound effect of this event upon his feelings is expressed in the most touching sentences he ever wrote, and to which there are few parallels in literature. It induced him to settle as near as possible to the place where she was buried. It thus became his habit to spend a great part of each year in his cottage at Avignon.

He soon reappeared as an author. His essay on "*Liberty*" was published in 1859. It had been planned and written as a short paper in 1854. It was in mounting the steps of the Capitol in the following year that the thought suggested itself of converting it into a volume. The essay is a vindication of the importance to society, and for the discovery of truth, of giving men full freedom to expand themselves in opposite and even conflicting directions, limited only by the prevention of injury to others. This little volume may be supposed to have had no inconsiderable effect in promoting that toleration for the free expression of opinion, even regarding beliefs longest revered, which, compared with the past, is a remarkable characteristic of this generation in Great Britain.

In the same year Mr Mill republished, in a collected form, in two volumes, under the title of "*Dissertations and Discussions*," articles formerly contributed to the "*London*," "*London and West-*

minster," and "Edinburgh" Reviews, as well as to other periodicals: a third volume followed in 1867. A pamphlet of "Thoughts on Parliamentary Reform" was also produced in 1859. In 1861 he published "Considerations on Representative Government."

In 1862 the essay on "Utilitarianism" appeared. It contains his latest view of ethical theory, and of the new criterion of morality which it was one great endeavour of his life to make known.

Mr Mill's principal contribution to analytical psychology and metaphysics was made in 1865. It took the form of an "Examination of Sir William Hamilton's Philosophy;" a large and elaborate volume, equal in scope and comprehensiveness to his greatest works. The "Examination" is a sort of philosophical supplement to his "Logic," in which many of the principles here argued had been silently assumed. Its tendency is to promote an explanation, through circumstances and association, of beliefs and feelings, which are apparently necessary and universal; in opposition to those who treat them as ultimate elements of human nature, and even as absolute or ontological necessities of reason. By Mr Mill this, like other questions, was not regarded as a mere matter of abstract speculation. Like his illustrious predecessor Locke, he thought he saw, in a prevailing tendency to consider some principles to be independent of the verification of experience, one of the most powerful obstructions to the efforts of the social reformer; and, like his predecessors on the same path, it may be thought that his theory makes science speculatively impossible for man. If rationality in nature is the basis of science, knowledge must presuppose reason in nature as the condition of its own existence; and then all ordinary inductive verification proceeds on the assumption of beliefs which do not admit themselves of being verified by observation.

This remarkable essay in metaphysics was followed by an essay in which he offers his final estimate of "Auguste Comte and Positivism."

After this productive literary period, Mr Mill was withdrawn for three years from his studious seclusion at Avignon. At the general election in 1865 he was chosen member for Westminster, and he appeared in the House of Commons when Parliament met in February 1866. In that and the two following sessions he was an

active and deeply interested member of the House of Commons—sessions of Parliament which passed the second Reform Bill. He spoke occasionally, and was heard with respect and curiosity, as the representative of large philosophical principles and a sort of philanthropic socialism. The advocacy of women's suffrage is that perhaps with which his Parliamentary name is most associated. In these years in England, he lived at Blackheath.

One result of the general election in November 1868 was to send Mr Mill back to his old pursuits, and to seclusion at Avignon. The Parliamentary episode had not indeed entirely interrupted his studies. In 1866 he read through Plato, as a preparation for a review of Grote. A fervid pamphlet in the same year, on "England and Ireland," urged a radical reform in the land system of the sister island. In 1867 he delivered an elaborate address on the Higher Education to the students of the University of St Andrews, who had chosen him as their Rector. He was also employed about a new edition of his father's "Analysis of the Human Mind," in conjunction with Mr Grote, Professor Bain, and our townsman Dr Findlater, which was published in 1869.

The years which followed Mr Mill's short Parliamentary career were mostly spent at Avignon, where he continued his life of literary labour. His essay on the "Subjection of Women" appeared in 1869, and this, with his efforts in Parliament, helped to make the education, and the political and social condition of the sex one of the questions of the day. His last published writing in philosophy of which I am aware was a review, in November 1871, of the Clarendon Press edition of Berkeley's works. He had always been a great admirer of Berkeley. In this essay he expresses the opinion that "of all who from the earliest times have applied the powers of their minds to metaphysical inquiries, Berkeley was the one of greatest philosophical genius; though among these are included Plato, Hobbes, Locke, Hartley, and Hume, as well as Des Cartes, Spinoza, Leibnitz, and Kant." But it was the negative and analytic side of Berkeley that he admired; he had no appreciation of the constructive part of his doctrine, on which Berkeley himself lays most stress.

In March of last year, Mr Mill visited London, and lived for six weeks in a suite of rooms he had taken in Victoria Street,

Westminster. He spoke at a meeting on the land question, in support of his opinion with regard to "the unearned increment in the value of land." He had previously published "Chapters and Speeches on the Irish Land Question," followed by a "Programme of the Land Tenure Reform Association." During these weeks in London he mixed much in society. The writer of this Notice spent part of Mr Mill's last day in England with him in his rooms in Westminster, when he seemed full of physical and intellectual vigour, and indulged in youthful recollections of his father and of Bentham. Next day, the 18th of April, he returned to Avignon. On Saturday the 3d of May, he made a long botanising excursion in that neighbourhood. Botanical research had been an enthusiasm of his life, and his original collection of herbaria is, I believe, of great value. He caught a chill on his way home. It issued in a severe form of erysipelas, of which he died on the morning of the following Thursday. He was buried the day after beside his wife. The Protestant pastor, the physician, and his domestic servant, formed the small company of mourners who saw him laid in his grave.

Mr Mill's appearances in public in his later years, aided by the art of the photographer, have made his earnest, thoughtful face, with its sensitive, nervous action, familiar to many. A refined, delicate organism, and wiry form, suggested the moderately good health which, notwithstanding extraordinary intellectual labour he enjoyed through life. He was fond of walking; allured by his love of botany and his passion for rural nature. He was a great reader of all sorts of current and periodical literature. His conversation, like his books, was remarkable for its abundance of logically digested information, judiciously deliberate, distinct, and everywhere vivified by the presence of active intelligence. He showed little or no appreciation of humour, but both his spoken and written words revealed a subdued and grave emotional fervour, especially for the propagation of opinions in which he believed, and the promotion of social changes which he supposed to be advantageous.

Probably no contemporary has modified more than Mr Mill the tone and manner of thinking of the fairly-educated community in Great Britain. The time is hardly come, however, for a satisfac-

tory estimate of what he has done, what he has failed to do, and what his influence in the future is likely to be. The habit of thinking characteristic of this generation is too much affected by his logical methods, and pervaded by his spirit, to admit of a perfectly just estimate.

That he has been in a great degree the representative English thinker of his generation will be generally allowed; for we already see enough to recognise in him the leader in this age of that school of British philosophy, which, in the seventeenth century, was represented by Hobbes and Locke, and in last century by Hartley and Hume. If he wanted the rugged masculine vigour and originality of Hobbes, he had more ardent sympathies and a more indulgent candour. Locke undoubtedly far excelled him in massive common sense and in practical knowledge of human nature, and was more complete as a man; but he was hardly superior as a subtle analytical psychologist, or equal as a lucid expositor. If Mr Mill wanted Hume's grace, humour, gaiety of temper, and insight, in the expression of a philosophy of life in a large degree common to them both, he had a moral earnestness and intensity of sentiment which one does not find in Hume. Mill was eminently a logician rather than a metaphysician or a speculative moralist; his conception of life was limited in its scope and aim. He methodised the experience of an age devoted to the physical sciences, and tending towards materialism. He was not a speculative philosopher, who sought to comprehend the universe: he was a reformer who wanted to make society better, by improving its relations to its circumstances on this planet. He accordingly explained to his countrymen their own scientific habits of research, in which inductive methods and presuppositions are employed with extraordinary vigour and success, for the improvement of circumstances and of the external arrangements of society. As a metaphysician, he always tried to keep speculation within the limits of positive science, and to dissolve by analysis, as hurtful prejudices, the faith or thought which does not admit of ordinary inductive verification,—thus, it may be alleged, overlooking in man, and withdrawing from human life, some of their best and noblest possessions.

Yet in some of their aspects Mr Mill's life and writings witness to a broader and deeper philosophy than he professed. His heart and his

sympathies outgrew the adverse influences of a sunless childhood. And his doctrines in metaphysics and ethics sometimes, I think, unconsciously recognise principles which break the logical symmetry of his professed Utilitarianism and philosophy of Custom and Association, producing, as in the case of Locke and others, an ambiguity in the exposition of his most important conclusions. As Sir James Mackintosh suggests of David Hume, it would indeed be a matter of wonder if his esteem for moral excellence should not at least have led him to envy those who are able to contemplate the perfection of excellence in the Supreme Reason that is accepted by them as the support of their lives, and the all-reconciling unity of existence.

2. Obituary Notes of the Rev. Dr Guthrie. By the Rev. Dr Lindsay Alexander.

Dr Thomas Guthrie was a native of Brechin, where he was born on the 12th of July 1803. His father, David Guthrie, was one of the principal merchants in that ancient city, and long occupied an influential position in it, being versant in all its affairs, and for several years holding the place of chief magistrate. Thomas was his sixth son. Having received a sound elementary education under different teachers in Brechin and the vicinity, Thomas was, at the early age of twelve, entered as a student in the University of Edinburgh; and there, for ten consecutive sessions, he continued prosecuting studies through the prescribed curriculum in arts and divinity, with the addition of certain branches of natural science, to which he spontaneously betook himself. In 1825 he received from the Presbytery of Brechin license as a preacher, and began forthwith to preach as occasion presented itself. Shortly after he was offered the presentation to an important charge, but as the offer was clogged with conditions which appeared to him to threaten his independence of thought and action he declined it; and no other professional opening appearing he went to Paris, where, for the best part of a year, he prosecuted medical studies at the Sorbonne, attending the lectures of Gay-Lussac, Thenard, and St Hilaire, and witnessing surgical operations by Dupuytren and Lisfranc at the hospitals. On his return home, being still dis-

appointed in his professional prospects, he purposed spending a year at one of the German universities, but from this he was turned aside in consequence of the death of his elder brother, who was a banker in Brechin, and who, dying somewhat suddenly, left his business in danger of being transferred to other hands, unless some one should be found to carry it on until such time as his son, then a boy, should be able to succeed him. In this emergency the only one of the family who was free to come to the help of the minor was his uncle Thomas, and he at once threw himself into the breach, and for two years conducted the business of the bank. On this he looked back with satisfaction as affording not the least valuable part of his training and education, as it brought him acquainted with the busy world, enlarged his knowledge of men and things, and gave him an aptitude for the management of affairs of which he found the advantage in after life. Whilst engaged in the business of the bank he did not intermit his studies or neglect opportunities of preaching when these were offered to him. He thus let it be known that he had no intention of abandoning his proper profession, and was only waiting till some suitable sphere was opened for him to enter upon the active discharge of its duties. Such a sphere was at length obtained by his being presented to the church and parish of Arbirlot, in Forfarshire, where he was ordained minister on the 13th of May 1830. Here he continued to labour with much assiduity and success for seven years, caring not only for the spiritual interests of his people, but bringing all the resources which previous culture and observation, as well as natural ability and good sense, had enabled him to accumulate, to bear upon the promotion of their temporal welfare. Here he laid the foundation of that eminence as a preacher which he afterwards attained, and here also he entered on that acquaintance with the condition, habits, wants, and perils of the poor, which in after years he turned to such excellent account in his philanthropic efforts. The fame of his power in the pulpit as a preacher, as well as of his administrative ability in his parochial cure, having reached the metropolis, where personally he was a stranger, he was in 1837 presented to the church and parish of Old Greyfriars, Edinburgh, as colleague with the late Rev. J. Sym. This charge he accepted, on the understanding that he would

exchange it for a single charge as soon as arrangements could be made for erecting a new parish in one of the more densely crowded and spiritually destitute parts of the city. This was accomplished when the new church was built in what used to be the West Bow, but where Victoria Street now stands; and on this Mr Guthrie entered as the minister of the new parish of St John's in 1840, determined, as far as in him lay, to work out the theory of the old parochial system in the centre of the city, and among a population many of whom were sunk in vice and degradation. Here he continued till the great secession from the Church of Scotland in 1843, when, having cast in his lot with the retiring party, of whose principles he cordially approved, and in whose proceedings he had taken an active share, he resigned his parochial charge and removed from the church of St John's, carrying with him his congregation. After some time, during which he preached in the Methodist Chapel, Nicolson Square, a new place of worship was erected not far from that which he had left, and to this, which came to be called Free St John's, he removed in 1844. In this church, where subsequently he had for his colleague the Rev. Dr Hanna, he continued to preach from Sunday to Sunday to audiences which crowded every corner, where room to sit or to stand could be found, for twenty years. During this period he was undoubtedly the most popular preacher in Scotland, perhaps in Britain. Persons of all ranks, and of every variety of culture, were found among his regular auditors; and illustrious strangers, statesmen, economists, and men of literature who visited the city, were often seen in the crowded pews. The care which he bestowed on the preparation of his discourses, the skill with which he arranged his topics, the vigour and perspicuity of his style, and, above all, the felicity of his illustrations and the truth and vividness of his descriptions, with the earnestness of his tone and the ease and naturalness of his delivery, combined to secure him this pre-eminence among the pulpit orators of his day.

But it was not only in the pulpit that, at this time, Mr Guthrie distinguished himself and drew to him popular esteem and homage. Even more, perhaps, as a philanthropist than as a preacher was his fame spread through the community. In him all good causes found an able and willing advocate; but it is chiefly with efforts

for the prevention of intemperance, and the rescue of destitute and degraded children, that his name is associated. Though not exactly the founder of ragged schools, he was the first to take a just estimate of their importance, the first to arouse the community in their favour, and the first to organise them formally and on an adequate scale; and to his powerful advocacy and persevering assiduity and care it is chiefly owing that these institutions are now so firmly established throughout the kingdom, where they have largely contributed to diminish pauperism, prevent crime, and add to the industrial strength of the nation. If his efforts for the suppression of intemperance have not met with the same success it is not because these were put forth with less zeal, perseverance, and self-denial on his part, but because the evil has grown to such a gigantic height as to render almost hopeless all attempts to remove or cure it. Nor, in referring to his labours for the benefit of others, should his great effort to raise money for the erection of comfortable residences for his brethren in the ministry be overlooked or mention of it omitted,—an effort to which, at a great amount of personal sacrifice, he devoted an entire year, traversing the country from end to end, visiting family after family, “from Cape Wrath to the Border, and from the German to the Atlantic Ocean,” and bringing into the treasury of his Church, for the purpose he had in view, upwards of L.116,000. It was when appearing on the platform, as the advocate of such schemes of benevolence, that he came out in all his strength as an orator. On such occasions all his faculties had full play, and his mastery over his audience was complete—at one time guiding their judgments by reasoning and strong good sense, at another, bearing them along on the stream of impassioned declamation—now melting them to tears by some deep touch of pathos or some thrilling tale of sorrow or of suffering, and anon convulsing them with laughter by some rich stroke of humour, some amusing description, or some ludicrous anecdote. The only weapon of the orator which he did not use was sarcasm, for which his kindly nature had no taste.

In recognition of his abilities and valuable public services, the University of Edinburgh conferred on him, in 1849, the degree of D.D. In May 1862 he was raised to the Moderator's chair in the

twentieth General Assembly of the Free Church of Scotland,—a dignity which, in all probability, would have been conferred on him some years earlier had the state of his health permitted him to undertake the duties of the office.

Gifted with a vigorous constitution, Dr Guthrie had enjoyed good health, notwithstanding the excitement and toil attendant on the discharge of his official functions and his philanthropic efforts. But the continuous over-exertion to which he was exposed, especially in connection with the Manse scheme, began at length to tell upon him, and alarming symptoms, the prelude of that disease which ultimately carried him off, became apparent. By the advice of medical friends he was induced, though reluctantly, to retire from the public exercise of his ministry, and from all engagements that might have an exciting effect upon the system. This took place in 1864, when a valuable testimonial was presented to him, amounting to L.5000, contributed by friends and admirers in all parts of the kingdom. On his retirement from the pulpit, Dr Guthrie devoted himself chiefly to literary pursuits. He became editor of the "Sunday Magazine," and contributed largely to its pages. Whilst thus employed he found time to make repeated excursions to the continent; and of his contributions to the "Sunday Magazine" not the least striking and instructive is a series of papers containing graphic sketches of what he saw when abroad, with characteristic observations and reflections on the scenes and incidents he describes. Most of his papers in the magazine were subsequently collected and published separately. These, with some volumes of sermons and a few pamphlets, comprise Dr Guthrie's efforts as an author. His writings have been widely circulated in Great Britain, the colonies, and the United States, and have afforded instruction and delight to thousands who never saw his face or heard his voice.

After his retirement from the pulpit Dr Guthrie was enabled to continue his literary labours in the enjoyment of a considerable measure of vigour till towards the close of 1872, when his illness began to assume a more virulent form. In the beginning of the following year he went to St Leonards-on-the-Sea, to obtain the benefit of the milder climate of that locality; and there, on the 24th of February, he closed his mortal career. His remains were

brought to Edinburgh, and were interred in the Grange Cemetery. The funeral was attended by a very large company, including the magistrates and council of the city, ministers of nearly every denomination, both in the city and from different parts of the country, representatives of various public bodies, the directors and children of the Original Ragged School, as well as the personal friends and relations of the deceased. The procession extended for about three quarters of a mile, and moved through an immense crowd of people of all classes, assembled to show the last mark of respect to one than whom no citizen of Edinburgh was better known or more universally esteemed, as well for his private virtues and noble character as for his unwearied exertions for the benefit of others, especially for the relief of the destitute and the recovery of the fallen.

3. Obituary Notice of Mr R. W. Thomson. By Professor Fleeming Jenkin.

MR R. W. THOMSON, most widely known as the inventor of the road-steamer, died on the 8th of March 1873, in the fiftieth year of his age. By his death the community has lost a distinguished engineer, a remarkable thinker, and a highly original inventor.

Born in 1822, in Stonehaven, Mr Thomson furnishes one more example of the many Scotchmen who by sheer force of character, without any adventitious aid, have risen to be leaders in their profession and benefactors to their country. His father started on a small scale the only factory which even now Stonehaven possesses, and destined his eldest son (the subject of our memoir) to the pulpit, but the lad showed such dislike to classical studies that he was sent to Charleston, U.S., at the age of fourteen, to be educated as a merchant. Commerce proved as distasteful as the classics, and he returned at the age of sixteen to this country, where he began his self-education, aided materially by a weaver who chanced to be a mathematician.

Now, when scientific and technical education is almost thrust upon careless students, it is well to remember how this able and successful engineer acquired his knowledge, and to learn that energy in the pursuit of science is far more important than the

most elaborate machinery for its distribution. At this time Mr Thomson conceived the idea of the ribbon saw, afterwards worked out by other hands. The elliptic rotary steam-engine, to which he afterwards gave much time, was also then first conceived by him. He gained some experimental knowledge of chemistry and electricity, and his successful application of these sciences in after years proves the rare judgment with which he directed his studies. A short practical apprenticeship in workshops at Aberdeen and Dundee formed the next step in his education. He had great pleasure in telling how the foreman at the end of the first fortnight's work paid him more than he expected to receive, and when the apparent error was pointed out, told him that there was no mistake, "he was worth it." He was next employed by a cousin, Mr Lyon (the builder of the Dean Bridge), in connection with the blasting by which Dunbar Castle was blown down, and on this occasion conceived the happy idea of firing mines by electricity. Having brought his idea into a practical form, he went at the age of nineteen to London. Faraday, to whom the invention was shown, gave him hearty encouragement; and Sir William Cubitt was so much struck by the idea that he at once gave him an important charge in connection with the blasting operations then in progress near Dover. About this time he was engaged with a civil engineer in Glasgow, and subsequently passed into the employment of the Stephensons.

At the time of the railway mania, he was twenty-two years old, and began business on his own account, having a large staff, at ten guineas per diem, engaged in making plans and surveys for a line in the Eastern counties. He even achieved a triumph over Stephenson before a Parliamentary Committee, having refused to withdraw from competition at the instance of influential directors. The route he had chosen was ultimately adopted, although by other men, as the railway panic at the time stopped the undertaking.

Debarred by the result of the panic from prosecuting his profession as a business, Mr Thomson began again to invent, and devoted much time to the introduction of india-rubber tires, which he patented. The patent was not profitable, for the material was scarce and dear, and its manufacture ill understood; but he was fortunately rewarded at a later date by finding an important and

successful application for these tires in connection with his road-steamer. At this period of comparative leisure, he read much, and probably laid the foundation for that great cultivation and wide range of information which were so remarkable in the later years of his life.

When railway business revived, he did not seek to re-enter on the practice of this branch of his profession, which had no attractions for him, partaking as it does more of the nature of commerce than science. As a boy he nearly lost his place in the workshop by refusing to repeat some operation with which he was familiar, and as a man he never cared for the familiar routine which is most profitable. He sent in a creditable design for the great Exhibition of 1851, and a little invention of his, "the fountain pen," was sold in the building. In 1852 he went as agent for an engineering firm to Java, to erect some sugar machinery, and here he found a new field in which his powers could be worthily exerted. Although without capital, he was offered and he accepted a partnership in an important house shortly after his arrival. He then designed machinery for the manufacture of sugar so greatly superior to anything previously in use in the island, as to give a great impulse to the production of that commodity; and up to the time of his death he continued to supply the best machinery used in Java, where his honourable character commanded the unbounded confidence of the Dutch planters.

We owe perhaps the most universally useful of Mr Thomson's inventions to the refusal of the Dutch authorities to allow him to erect a waterside-crane, unless it could be removed every night, lest the natives should stumble over it. Mr Thomson hereupon designed the first portable steam-crane. He did not patent the idea, but Messrs Chaplin, who made the first small steam-crane for him, had, when he next re-visited England, two large factories engaged in the manufacture of these now indispensable appliances. The invention consisted mainly in employing the boiler as a counterpoise. In 1860 he re-visited Europe, to order a hydraulic dock consisting of a few types or classes of plates, each plate being interchangeable with every other plate of its class. He by this plan avoided the expense of double erection in England and abroad. The first dock thus made sunk when erected, in Mr

Thomson's absence, owing to the inexperience of the young engineer to whom it was intrusted. Fortunately two other docks from Mr Thomson's designs were in course of construction,—one for the French Government at Saigon, and the other for a company at Callao. These have been thoroughly successful.

In 1862 Mr Thomson retired from business in Java and settled in Edinburgh. He devoted much time and labour to perfecting the elliptic rotary engine, a clear and simple model of which may be seen in the Industrial Museum. His next invention, the Road Steamer, was the result of a direct practical want. An efficient traction engine was required for the transport of sugar-canes in Java, and none could be found capable of doing the work. Mr Thomson recurred to his old idea of india-rubber tires, and found in these a solution of the main difficulty in designing a traction engine. The tires are not fastened to the wheel, but adhere to it by friction. They form a broad pad or elephant's foot, by which the great weight of the engine is distributed over a large surface. The outer surface adapts itself to every peculiarity of the ground, and the inner surface forms, as it were, a constant endless platform on which the comparatively rigid engine works. The india-rubber does in a thoroughly practical manner what Boydell attempted to do by his impracticable endless railway. Both inventors wished to enable the steam-engine to work under constant conditions, but Mr Thomson's plan is strong, simple, and yielding, where Boydell's was weak, complex, and rigid. The perfect success of the plan is perhaps best attested by the numerous imitations which it has called forth, the object in most of these being to dispense with the expensive material india-rubber. The steel-protecting grooves for the tires are a later invention, and only a day or two before his death the inventor made an important improvement in their construction.

The zeal and energy of the true inventor in conquering difficulties and discouragement have often been told. Those who had the privilege of knowing Mr Thomson have seen this spectacle heightened in tragic interest by the grandeur of mind with which he contended against the terrible malady which has so much too soon closed his labours. If mental and moral qualities could be as simply described as mere mechanical inventions, more should

be said of the man, and less of the engineer. No written record can express the singular powers of Mr Thomson's mind and the charm of his character. The specialist in science, the professed chemist, the professed electrician, the professed geologist, the professed lawyer, all received suggestions from his fertile mind. The able and original paper on coal, read in this Society shortly before his death, affords an illustration of this sagacity of thought on subjects not specially his own. In art he had a cultivated taste, in narration and conversation he was unrivalled. All who conversed with him felt that they had never spoken so well themselves, and had seldom met with so sympathetic a listener. He had an untiring toleration for the failings of mankind, without abating for an instant in its application to himself the high standard which he shrank from applying to others. Even under terrible pain, his enjoyment of truth, of nature, of all that was noble, seemed not to flag. He never repined, but worked to the last hour, not with mere resignation, but with a noble contentment.

4. Obituary Notice of Archibald Smith. By Sir William Thomson.

[Abridged (by direction of the Author) from *Proc. R. S.*]

ARCHIBALD SMITH, only son of James Smith, of Jordanhill, Renfrewshire, was born on the 10th of August 1813, at Greenhead, Glasgow, in the house where his mother's father lived. His father had literary and scientific tastes with a strong practical turn, fostered no doubt by his education in the University of Glasgow, and his family connection with some of the chief founders of the great commercial community which has grown up by its side. In published works on various subjects he left enduring monuments of a long life of actively employed leisure. His discovery of different species of Arctic shells, in the course of several years' dredging from his yacht, and his inference of a previously existing colder climate in the part of the world now occupied by the British Islands, constituted a remarkable and important advancement of geological science. In his "Voyage and Shipwreck of St Paul," a masterly application of the principles of practical seamanship renders St Luke's narrative more thoroughly intelligible to us now

than it can have been to contemporary readers not aided by nautical knowledge. Later he published a "Dissertation on the Origin and Connection of the Gospels," and he was engaged in the collection of further materials for the elucidation of the same subject up to the time of his death, at the age of eighty-five. Archibald Smith's mother was also of a family distinguished for intellectual activity. Her paternal grandfather was Dr Andrew Wilson, Professor of Astronomy in the University of Glasgow, whose speculations on the constitution of the sun are now generally accepted, especially since the discovery of spectrum-analysis and its application to solar physics. Her uncle, Dr Patrick Wilson, who succeeded to his father's Chair in the University, was author of papers in the "Philosophical Transactions" on Meteorology and on Aberration.

Archibald Smith's earliest years were chiefly passed in the old castle of Roseneath. In 1818 and 1819 he was taken by his father and mother to travel on the continent of Europe. Much of his early education was given him by his father, who read Virgil with him when he was about nine years old. He also had lessons from the Roseneath parish schoolmaster, Mr Dodds, who was very proud of his young pupil. In Edinburgh, during the winters 1820-22, he went to a day school; and after that, living at home at Jordanhill, he attended the Grammar School of Glasgow for three years. As a boy he was extremely active, and fond of everything that demanded skill, strength, and daring. At Roseneath he was constantly in boats; and his favourite reading was anything about the sea, commencing, no doubt, with tales of adventurers and buccaneers, but going on to narratives of voyages of discovery, and to the best text-books of seamanship and navigation as he grew older. He had, of course, the ordinary ardent desire to become a sailor, incidental to boys of this island; but with him the passion remained through life, and largely influenced the scientific work by which he has conferred never-to-be-forgotten benefits on the marine service of the world, and made contributions to nautical science which have earned credit for England among maritime nations. He was early initiated into practical seamanship under his father's instructions in yacht sailing. He became an expert and bold pilot, exploring and marking passages and anchorages for

himself among the intricate channels and rocks of the West Highlands, when charts did not supply the requisite information. His most loved recreation from the labours of Lincoln's Inn was always a cruise in the West Highlands. In the last summer of his life, after a naturally strong constitution had broken down under the stress of mathematical work on ships' magnetism by night, following days of hard work in his legal profession, he regained something of his health and strength in sailing about with his boys in his yacht, between the beautiful coasts of the Firth of Clyde, but not enough, alas! to carry him through unfavourable influences of the winter that followed.

In 1826 he went to a school at Redland, near Bristol, for two years; and in 1828 he entered the University of Glasgow, where he not only began to show his remarkable capacity for mathematical science in the classes of Mathematics and Natural Philosophy, but also distinguished himself highly in classics and logic. Among his fellow-students were Norman Macleod and Archibald Campbell Tait, with both of whom he retained a friendship throughout life. After completing his fourth session in Glasgow, he joined in the summer of 1832 a Cambridge reading party, under Hopkins, at Barmouth in North Wales, and in the October following commenced residence in Trinity College, Cambridge.

While still an undergraduate he wrote and communicated to the Cambridge Philosophical Society a paper on Fresnel's wave-surface. The mathematical tact and power for which he afterwards became celebrated were shown to a remarkable degree in this his first published work.

In 1836 he took his degree as Senior Wrangler and first Smith's Prizeman, and in the same year he was elected to a Fellowship in Trinity College.

Shortly after taking his degree, he proposed to his friend Duncan Farquharson Gregory, of the celebrated Edinburgh mathematical family, then an undergraduate of Trinity College, the establishment of an English periodical for the publication of short papers on mathematical subjects. Gregory answered in a letter of date December 4th, 1836, cordially entering into the scheme, and undertaking the office of editor. The result was the "*Cambridge Mathematical Journal*," of which the first number appeared in

November 1837. It was carried on in numbers, appearing three times a year, under the editorship of Gregory, until his death, and has been continued under various editors, and with several changes of name, till the present time, when it is represented by the "Quarterly Journal of Mathematics" and the "Messenger of Mathematics." The original "Cambridge Mathematical Journal" of Smith and Gregory, containing as it did many admirable papers by Smith and Gregory themselves, and by other able contributors, early attracted to it, among whom were Greatheed, Donkin, Walton, Sylvester, Ellis, Cayley, Boole, inaugurated a most fruitful revival of mathematics in England, of which Herschel, Peacock, Babbage and Green, had been the prophets and precursors.

It is much to be regretted that neither Cambridge nor the university of his native city could offer a position to Smith, enabling him to make the mathematical and physical science for which he felt so strong an inclination, and for which he had so great capacity, the professional work of his life. Two years after taking his degree, he commenced reading law in London, but his inclination was still for science. Relinquishing reluctantly a Trinity Lectureship offered to him by Whewell in 1838, and offered again and almost accepted in 1840, resisting a strong temptation to accompany Sir James Ross to the Antarctic regions on the scientific exploring expedition of the "Erebus" and "Terror" in 1840-41, and regretfully giving up the idea of a Scottish professorship, which, during his early years of residence in Lincoln's Inn, had many attractions for him, he finally made the bar his profession. But during all the long years of hard work, through which he gradually attained to an important and extensive practice, and to a high reputation as a Chancery barrister, he never lost his interest in science, nor ceased to be actively engaged in scientific pursuits; and he always showed a lively and generous sympathy with others, to whom circumstances (considered in this respect enviable by him) had allotted a scientific profession.

About the year 1841 his attention was drawn to the problem of ships' magnetism by his friend Major Sabine, who was at that time occupied with the reduction of his own early magnetic observations made at sea on board the ships "Isabella" and "Alexander," on the Arctic Expedition of 1818, and of corres-

ponding magnetic observations which had been then recently made on board the "Erebus" and "Terror" in Captain Ross's Antarctic Expedition of 1840-41. The systematic character of the deviations, unprecedented in amount, experienced by the "Isabella" and "Alexander" in the course of their Arctic voyage, had attracted the attention of Poisson, who published in 1824, in the "Memoirs of the French Institute," three papers containing a mathematical theory of magnetic induction with application to ships' magnetism. The subsequent magnetic survey of the Antarctic regions, of which by far the greater part had to be executed by daily observations of terrestrial magnetism on ship-board, brought into permanent view the importance of Poisson's general theory; but at the same time demonstrated the necessity for replacing his practical formulæ by others, not limited by certain restrictions as to symmetry of the ship, which he had assumed for the sake of simplicity. This was the chief problem first put before Smith by Sabine, and his solution of it was the first great service which he rendered to the practical correction of the disturbance of the compass caused by the magnetism of ships.

In 1850 he published separately an account of his theoretical and practical investigations on the correction of the deviations of a ship's compass, which was afterwards given as a supplement to the Admiralty "Practical Rules" in 1855. The large deviations found in iron-plated ships of war "having rendered necessary the use of the exact instead of the approximate formulæ," this article was rewritten by Smith for the Compass Department of the Admiralty. It now forms Part III. of the "Admiralty Manual for the Deviations of the Compass," edited by Evans and Smith, to which are added appendices containing a complete mathematical statement of the general theory, proofs of the practical formulæ, and constructions and practical methods of a more mathematical character than those given in the body of the work for ordinary use. A separate publication, of "Instructions for Correcting the Deviation of the Compass," by Smith, was made by the Board of Trade in 1857.

It is satisfactory to find that the British Admiralty "Compass Manual," embodying as it does the result of so vast an amount of labour, guided by the highest mathematical ability and the

most consummate practical skill, has been appreciated as a gift to the commonwealth of nations by other countries than our own. It is adopted by the United States Navy Department, and it has been translated into Russian, German, Portuguese, and French. Smith's mathematical work, and particularly his beautiful and ingenious geometrical constructions, have attracted great interest, and have called forth fresh investigation in the same direction, among the well-instructed and able mathematicians of the American, Russian, French, and German Navy Departments.

The constancy to the compass problem, in which Smith persevered with a rare extreme of disinterestedness, from the time when Sabine first asked him to work out practical methods from Poisson's mathematical theory, until his health broke down two years before his death, was characteristic of the man. It was pervaded by that "*ténacité passionnée*" which a generous French appreciation describes as a peculiarity of the English nation; but there was in it also a single-mindedness and a purity of unselfishness to be found in few men of any nation, but simply natural in Archibald Smith.

Honourable marks of appreciation reached him from various quarters, and gave him the more pleasure from being altogether unsought and unexpected. The Admiralty, in 1862, gave him a watch. In 1864 he received the honorary degree of LL.D. from the University of Glasgow. The Royal Society awarded to him the Royal Medal in the year 1865. The Emperor of Russia gave him, in 1866, a gold compass, emblazoned with the Imperial Arms and set with thirty-two diamonds, marking the thirty-two points. Six months before his death Her Majesty's Government requested his acceptance of a gift of L.2000, as a mark of their appreciation of "the long and valuable services which he had gratuitously rendered to the Naval service in connection with the magnetism of iron ships, and the deviations of their compasses." The official letter intimating this, dated Admiralty, July 1st, 1872, contains the following statement, communicated to Smith by command of the Lords of the Admiralty:—"To the zeal and ability with which for many years you have applied yourself to this difficult and most important subject, My Lords attribute in a great degree the accurate information they possess in regard to the influence of magnetism, which has so far conduced to the safe navigation of iron

ships, not only of the Royal and Mercantile Navies of this country, but of all nations."

In private life those who knew Archibald Smith best loved him most; for behind a reserve which is perhaps incident to engrossing thought, especially when it is concerned with scientific subjects, he kept ever a warm and true heart; and the affectionate regrets of his friends testify to the guileless simplicity and sweetness of his disposition, which nothing could spoil or affect. About the close of 1870 he was compelled by ill-health to give up work, but two years later he had wonderfully rallied; and though he was not strong enough to resume his legal or scientific work, he was able to take his old interest in his boys' mathematical studies. A few weeks before his death he revised the instructions for compass observations to be made on board the "Challenger," then about to sail on the great voyage of scientific investigation now in progress; and he spoke several times of the satisfaction it gave him to feel able again to do such work without effort or fatigue. The attack of illness which closed his life was unexpected and of but a few hours' duration. In 1853 he married a daughter of Vice-Chancellor Sir James Parker, then deceased, and he leaves six sons and two daughters. He died on the 26th of December 1872.

The following Gentlemen were elected Fellows of the Society:—

A. FORBES IRVINE, Esq.

BENJAMIN CARRINGTON, M.D., Eccles, Lancashire.

WILLIAM FERGUSON, F.L.S., F.G.S.,

T. B. SPRAGUE, M.A. Cantab.

THOMAS MUIR, M.A.

J. BATTY TUKE, M.D., F.R.C.P.E.

WILLIAM DURHAM, Esq.

Monday, 16th February 1874.

SIR W. THOMSON, President, in the Chair.

The following Obituary Notices of Deceased Fellows of the Society were read :—

1. Obituary Notice of the Very Rev. Dean Ramsay.
By the Rev. D. F. Sandford.

The Very Reverend EDWARD BANNERMAN RAMSAY, Dean of the Diocese of Edinburgh, in the Episcopal Church of Scotland, was born in Aberdeen on the 31st day of January 1793. His father was Sir Alexander Ramsay, Bart., of Balmain and Fasque. Sir Alexander was the second son of Sir Thomas Burnett, Bart., of Leys, but had assumed the name of Ramsay, and been created a Baronet, on succeeding to the estates of his maternal uncle in Forfarshire. He was by profession an advocate at the Scottish bar, and Sheriff of his native county of Kincardine. In that county the family of Burnett of Leys have held lands and a high position for many hundred years. Bishop Burnet of Salisbury, the historian of his own times, and a divine of enlarged mind and liberal views, belonged to it. The Bishop's picture, in his robes as Chancellor of the Order of the Garter, is among the family portraits at Crathes Castle, the seat of the present Sir James Burnett, Bart.

The Dean's mother was Elizabeth, eldest daughter and co-heiress of Sir Alexander Bannerman, Bart., of Elsick, a lady of considerable personal attractions and marked character. She and her husband were in Paris at the outbreak of the great French Revolution. They escaped from France under the protection of a tricolour cockade worn by the Sheriff, which Dean Ramsay presented some years ago, as an interesting relic of the time, to the Antiquarian Museum in Edinburgh. On reaching Scotland they settled at Aberdeen, and so Edward Bannerman, their fourth son, who was born soon after, first saw the light in his own ancestral country. This was always a subject of deep gratification to one whose whole heart and sympathies were so eminently Scottish. In early life Edward Ramsay was sent to reside with

his great-uncle, the then Sir Alexander Ramsay, who placed him at school in a small village near his own residence, Harlsey, in Yorkshire. The locality was a very retired one, and old customs lingered there which time had changed or obliterated in other parts of England. The Bible lay chained to the desk in the parish church, as in the days of Edward VI. and Queen Elizabeth. The bodies of the deceased were carried to the quiet churchyard by those of their own sex, age, and condition. The village girls bore their companions, the boys their schoolfellows, the young men and women, the middle-aged and the old, their contemporaries and associates who had been called away. The parish curate dined with the squire every Sunday, but did not omit to drink to the health of the old butler who waited at table, as well of his host, and the other guests. The village carpenter, a strange character, forestalled Archbishop Whately's historic doubts as to the existence of Napoleon Buonaparte, and boldly declared that he did not believe there was any such person. His conviction was that the name was used to frighten children, and to terrify the British nation into keeping up the army and navy, and paying the very heavy taxes imposed upon them. From this primitive spot, where doubtless his powers of observation and his interest in local peculiarities were first awakened by the circumstances just mentioned, which he never forgot, Ramsay was transferred to the Grammar School at Durham. Here, as he often stated with regret, he was taught little and learnt less. After leaving Durham, he was a pupil for a short time of Dr Joynes, a clergyman at Sandwich in Kent, and then entered St John's College, Cambridge, where he took his degree in 1816. Although not distinguished in any remarkable way as a scholar or mathematician in the University, Mr Ramsay seems to have felt satisfied with the result of more than one of the College examinations, and he obtained during his residence at St John's a scholarship on that learned foundation. Within a very short period after taking his degree, he received a title for holy orders as curate of Rodden in Somersetshire; and was ordained by the Bishop of Bath and Wells, Deacon in December 1816, and Priest in the following year. When acting in after life as examiner of candidates for the ministry, he frequently drew a comparison between the meagre superficial examinations,

confined to a paper on the Evidences of Christianity, and a few verses of the Greek Testament, to which he was subjected, and the more thorough and searching ordeal through which aspirants to the clerical office are now required to pass. He continued at Rodden for seven years, perhaps in some respects the happiest in his life. Although his rector was non-resident, he was allowed to conjoin the care of the neighbouring parish of Buckland with that of Rodden, and to discharge also for a time the duties of evening lecturer in the parish church of Frome. This afforded to him another contrast in his own remembrance with the present requirements as to residence, experience, and work on the part of the clergy. While at Rodden, he employed his leisure time and annual holiday in the study of botany, making more than one expedition into Wales and elsewhere with this object. He also gave some time to the cultivation of music, for which he had considerable talent. And he seems also to have turned his attention to mathematics and astronomy, incited thereto by his brother, the late Admiral Sir William Ramsay, who gave him a box of instruments and a telescope, which he used in the instruction of a class of young friends and parishioners.

After declining the offer of an appointment to a chapel in his native city, Aberdeen, Mr Ramsay came to Edinburgh, at the end of 1823, as curate to Mr Shannon, the incumbent of St George's Episcopal Chapel in York Place. This change of residence introduced him to Edinburgh at a time when not only agitation for political and municipal reform, but also the awakening of religious thought and feeling to which the Clapham School had given rise in England, and which was soon to merge in the remarkable Oxford movement of 1833, were intermingling with its intellectual culture and social life. The refined, cultivated, and earnest-minded young clergyman, possessing hereditary claims to be received among the highest circle of its inhabitants, soon established also close and intimate relations with many of those who then made our city so distinguished. He became popular in the best sense of the word. His ministrations and preaching were highly appreciated. His kindly pleasing manners and unaffected genuine character won for him an influence which was soon felt for good in many quarters. After serving the curacy of St George's

for two years, Mr Ramsay was appointed incumbent and pastor of the interesting old chapel and genuine Scottish Episcopalian congregation of St Paul's, Carrubber's Close, in the Old Town. The chapel was largely attended during his ministry, and the value of the living while he held it was L 400 per annum.

In 1827 he was appointed assistant minister of St John's, and, on the death of the late Bishop Sandford in 1830, was elected to the incumbency of that charge, which he continued to hold until his long and honoured life reached its close on the 27th December 1872. The more strictly professional details and characteristics of Mr Ramsay's career are not subjects of comment or notice in this place. It will suffice to mention that in the faithful and assiduous discharge of his duties he secured to himself appreciation, confidence, and esteem, which, as years rolled on and in proportion as he became better known, grew and ripened into genuine and universal regard and love.

In 1838 he proposed and carried through the General Synod of the Scottish Episcopal Church a canon for establishing a society, the main object of which was to supplement the very inadequate stipends of the clergy, to provide teachers for the poor, and generally to improve the financial condition of the Communion to which he belonged. He was specially useful as a catechist among the young of his flock, and compiled a manual of catechetical instruction for their use, which has passed through more than twelve editions. He published a volume of Advent Sermons, also pastoral letters addressed to his congregation on various subjects, occasional sermons and pamphlets on matters connected with his own communion, and a series of Lectures on Diversities of Character, and another series on Faults in Christian Believers, which were subsequently combined and expanded into a Treatise on the Christian Life. In 1841 Mr Ramsay was appointed by Bishop Terrot, on his own elevation to the Episcopate, Dean of the Diocese of Edinburgh. In 1845 he was offered by Sir Robert Peel, on behalf of the Crown, the Bishopric of New Brunswick in Nova Scotia, and in 1848, and again in 1862, he was elected by the clergy of two Scottish dioceses to be their Bishop. But he saw fit to decline on each of these occasions the offer of a mitre, much to the satisfaction of his own congregation, who viewed with little favour these

attempts to deprive them of their tried and valued friend and pastor. In 1859, on the occasion of the installation of his distinguished friend, Mr Gladstone, as Lord Rector, the University of Edinburgh conferred on the Dean the degree of LL.D. In 1828-1829, he was one of the secretaries of the ordinary meetings of the Royal Society. He subsequently became a member of Council, and in 1859 a Vice-President. In 1861 he opened the winter session with an address from the chair, which was published in the Proceedings. The only paper contributed by him to the Society's General Transactions was a biographical memoir of the late Dr Chalmers, with whom he was on terms of intimate friendship. A few years ago he inaugurated a movement for erecting a statue of the same eminent philosopher and divine, which is now approaching completion in the studio of Mr John Steele, and is to be placed at the intersection of George Street and Castle Street in this city.

The Dean's continued interest in botanical study was evinced by his publishing a notice of the works and discoveries of his friend Sir J. E. Smith. His taste for the highest style of music, and his earnest desire to extend the knowledge and cultivation of it, led him to choose, as the subject of two lectures before the Philosophical Institution of Edinburgh, "The Genius and Works of Handel." They were delivered to a crowded audience in the Music Hall, with the assistance of illustrations by a choir, and were afterwards published. The Dean delivered before the same body a lecture on Pulpit Oratory and Orators, and pursued the subject thus suggested in a printed letter to a young clergyman on the art of clear and articulate public speaking, in which he was himself an unsurpassed proficient. The work, however, with which his name is most widely connected is his "Reminiscences of Scottish Life and Character." It has gone through twenty editions, and more than ninety thousand copies of it have been sold. It is to be found on the library tables of royalty and in the cottage of the peasant. It is sold by the newsboys at every railway station. It is to be seen in the huts of new settlements in Western America, and of the cattle and sheep runs of New Zealand and Australia. It has made the Dean's good Scottish name a household word in every land on which the sun shines. Wherever the exiled Scotchman goes, he carries with him the

"Reminiscences" as one of the links which will continue to bind his heart to his own country, and to keep alive in his memory the most vivid and pleasing recollections of her history and people. The object of the book was not to produce a mere momentary amusement, but to contribute to an important branch of historical science, the neglect of which has left us too ignorant of what our forefathers and their times really were. It was intended to preserve the remembrance of old Scottish customs, and of national peculiarities and characteristics, the traces of which, in many respects to our loss, are fast dying out. That jocular sayings and anecdotes should prove the staple of the work was an accident, or rather I might say a necessity, and not an arbitrary choice of the author. It may have its literary faults. But many of us were too partial to the man, too much in sympathy with his purpose and with the genuine, kindly, patriotic motives which guided his pen, to dwell on them. Nay more, critics have been slow to point them out, and the judgment of the public has done more than condone them. It may not be too much to apply to the "Reminiscences" the language which the greatest Scottish novelist has used with regard to his own works, and to say that the Dean was happy in the knowledge that the perusal of his book has amused hours of relaxation and relieved those of languor, pain, and anxiety, and that it has contributed in no small degree to the happiness and instruction of his fellow-countrymen. It is no little credit, the Dean felt it to have been a great privilege, to have followed, however humbly, in the footsteps of Sir Walter Scott, and to have added to the literature of his country a volume which must always serve to make Scotland better known, appreciated, and loved, wherever it is read.

We may not intrude into the sacred domestic circle to find material for this biographical notice; it may suffice to say that those who knew Dean Ramsay best loved him best. He was honoured above most men with the friendship of the good and great. Dignified ecclesiastics, eminent statesmen, nobles of character and renown no less exalted than their rank, sought and valued his acquaintance, his wise counsels, his kindly sympathy. Men of distinction and repute from all quarters found a welcome under his roof, and never left it without feeling that they had added to their circle of life-long friends.

In every philanthropic movement the Dean was ready to assist with his money and influence. He gave largely, from no great means, to charitable agencies and to individual cases of need and distress. He was a friend to those of every class with whom he was brought in contact. The cabmen vied with each other as to which of them should take him for his daily drive, and they counted his presence at more than one of their yearly social entertainments a special honour. Every one seemed gratified at any occasion for intercourse with him, even for a few moments. He was essentially a gentleman, dignified, courteous, and kindly. The Dean's influence in his own Communion was deservedly very great, and if it was exerted in every way in his power to advance her usefulness and prosperity, it was at the same time always tempered and guided by a spirit of charity and good-will, which enabled him to do more than almost any man of his day and generation to purify and sweeten the atmosphere both of social and ecclesiastical life in this city and country. Whatever estimate may be formed of the views he held, the work he did, this at least must be universally admitted, and may not unfitly be put on record even here. To Dean Ramsay, charity, freedom from bigotry, narrowness, and ill-will, were not the accidents of temperament, or the fruits of an easy disposition, of high breeding, and culture. They were essential elements in the ideas he had formed of the Christian religion and of the Christian character. He was never tired of enforcing them in his teaching, as he never ceased to illustrate and exemplify them in his conduct. And that his endeavours to do this by every means he could, and towards men of every creed and party known to the religious and political world, were acknowledged and appreciated, the great demonstration which took place at his funeral amply testified. It was not only in numbers one of the largest which ever took place in this city, but it was attended by the leading representatives, both lay and clerical, of every denomination. Men forgot their differences and the causes of their separation one from another, as they gathered round his grave. It was the realisation for once of the dream and aspiration of Dean Ramsay's own life. It was the most striking and worthy tribute which could possibly have been paid to his memory.

It will be well for religion, as, I may venture to add, it will be well also for learning, and science, and truth in all its forms and aspects, if the same spirit which breathed and spoke in all that Dean Ramsay did and said shall increase, and spread, and deepen among us, in our various spheres and callings. We cannot but feel that in every point of view Dean Ramsay's was a career which, as it was honoured while he was spared to us, and marked by such distinctions as befitted his position in the Church and in society during his life, so it demanded some tribute and notice in this place, now that his name is withdrawn from the roll of our living Fellows. If it was not given him to further the cause of science and learning, as many belonging to the Royal Society have done, yet his teaching and example were such as all may profitably recall to memory and strive to follow and imitate.

2. Obituary Notice of Professor Rankine.

By Lewis D. B. Gordon, C.E.

WILLIAM JOHN MACQUORN RANKINE was the son of Lieutenant David Rankine of the Rifle Brigade, younger son of Macorne or Macquorn Rankine, Esq., of Drumdow in Ayrshire, and thus of an ancient Scottish family. His mother was the elder daughter of Archibald Grahame, Esq., of Drumquhassell. He was born in Edinburgh, 5th July 1820. Rankine records of himself, "My earliest distinct recollection is that of my mother teaching me the Lord's Prayer, next my father explaining to me the character of Jesus Christ;" and further he records, "My early instruction in arithmetic and elementary mechanics and physics was mainly obtained from my father." The mutual dependency thus begun continued through as beautiful a life of mutual self-devotion between parents and son as can be pictured; for the three were rarely far separate during the fifty years the parents lived after his birth.

Rankine went to the Ayr Academy in 1828, and afterwards to the High School of Glasgow in 1830, and thence to Edinburgh, where he studied geometry under Mr George Lees; but his knowledge of the higher mathematics was chiefly obtained by private study. He records that in 1834 "My uncle Archibald Grahame

gave me a copy of 'Newton's Principia,' which I read carefully; this was the foundation of my knowledge of the higher mathematics and dynamics and physics." He read the Principia in the original Latin, and in after life recommended his pupils so to read this work of paramount authority and reputation; "for," said he, "modern science has added no new principle to the dynamics of Newton; what it has done is to extend the application of dynamical principles to phenomena to which they had not been previously applied; in fact, to the correlation of the physical sciences—or, in other words, what is denoted by the convertibility of energy." Thus, at the early age of fourteen, had Rankine begun to discipline his mind and train his analytical powers on Newton's model of unquestionable definition and exhaustive demonstration, characteristics of the many works on cognate subjects he was himself in after years to contribute for the education of engineers of every class, and for the advancement of physical science. For two years, from 1836 to 1838, Rankine was a student in the University of Edinburgh, and took the courses of Natural Philosophy, Chemistry, Natural History, and Botany. He continued for two sessions under Professor Forbes; and the first year gained the gold medal for "An Essay on the Undulatory Theory of Light," and the extra prize (gold medal) for "An Essay on Methods in Physical Investigation." At this period, too, he read much metaphysics, chiefly Aristotle, Locke, Hume, Stewart, Degerando. The whole tendency of his mind was to the digestion and assimilation of the highest human knowledge. But the *res angusta domi* demanded that he should take a profession; and at this period none was more in vogue, or apparently more promising of abundant employment, than that of a civil engineer.

Rankine having for a short time assisted his father, who was superintendent of the Edinburgh and Dalkeith Railway, in 1838 became a pupil of Mr M'Neil (afterwards Sir John M'Neil), whose practice in Ireland was varied and extensive. Accordingly, for four years Rankine was actively employed as a pupil on various surveys and schemes for river improvements, water works, and harbour works, and on the Dublin and Drogheda Railway. While on this work, he contrived and practised a method of "setting out curves" by chaining and angles at the circumference, since

known as *Rankine's method*. He was much loved and respected by his numerous fellow-pupils, several of whom have attained high professional status. His pupilage ended, Rankine returned to Edinburgh, and was occupied for some time in the preparation and publication of an "Experimental Inquiry into the Advantages attending the Use of Cylindrical Wheels on Railways."

The theoretical investigation, and the deductions from the results of the experiments, conducted by his father and himself, are characterised by the same completeness in every respect as his more important and more famous writings of maturer years. But cylindrical wheels never came into use. It was "too late" to begin an obvious improvement, or there was no time to think of it; and yet, taking everything into consideration, the wheels would be better cylindrical, so formed that they should retain that shape for the longest time.

In 1842-43 various papers were sent to the Institution of Civil Engineers, and prizes were granted for them. There is one on "The Fracture of Axles," in which the importance of continuity of form and fibre was first shown, and the hypothesis of spontaneous crystallisation disproved. The conclusions of this paper were generally accepted and acted upon in the construction of axles.

In 1844-45, and afterwards till 1848, Rankine was employed under Messrs Locke and Errington on various railway projects promoted by the Caledonian Railway Company, of which his father had become secretary. But from 1842 onwards his mind had been much occupied in perfecting himself in the use of the higher analysis and in its application to the mechanics of molecular vortices.

Rankine's first investigation of the principles of the mechanical action of heat appeared in a paper received by the Royal Society of Edinburgh in December 1849, and published in their Transactions, vol. xx. It is based on what he calls "the hypothesis of molecular vortices;" that is to say, the supposition that the motions of which Davy showed thermotic heat to consist are of the nature of vortices—whirls or circulating streams. This is the part of the hypothesis that is specially connected with the phenomena of the mechanical action of heat; but in order to connect these with some other phenomena, Rankine makes the

further suppositions that the whirling motion is diffused in the form of atmospheres round nuclei, which may be either bodies of a special kind or centres of condensation and attraction in the atmospheres; and that radiance, whether of heat or light, consists in the transmission of a vibratory motion of the nuclei, by means of forces which they exert on each other.

The *quantity of heat* in a body is the energy of its molecular vortices; the *absolute temperature* of the body is the same energy divided by a specific co-efficient for each particular substance. A *perfect gas* is a substance in which the elastic pressure is sensibly that which varies with the centrifugal force of the vortices only; and the intensity of the pressure, according to the known principles of mechanics, must be proportioned directly to the energy of the vortices, and inversely to the space that they occupy. In substances not *perfectly gaseous*, the elasticity is modified by attractive or cohesive forces. When the deviation from the perfectly gaseous state is small, the effects of such forces may be approximately represented by series, in terms of the reciprocal of the absolute temperature. Rankine had previously published an example of the use of such series, in a paper on the Elasticity of Vapours (Edin. Phil. Journal, July 1849), and he also applied them with success to the elasticity of carbonic acid and some other gases (Phil. Mag. 1851). *Sensible heat* is the energy employed in varying the velocity of the whirling particles; *latent heat* the work done in varying the dimensions of their orbits, when the volumes and figures of the spaces in which they whirl are changed. The force which keeps any particle in its orbit is equal and opposite to the centrifugal force of that particle; therefore the work done in varying the orbits of the particles is proportionate to their centrifugal forces, therefore to the energy of the vortices, therefore to the *absolute temperature*. And to compute that quantity of work, or latent heat, when a body undergoes a given variation of dimensions, the *absolute temperature* is to be multiplied by the corresponding variation of a certain function of the dimensions and elasticity of the body. This function is computed by taking the rate of variation with temperature, of the external work done during the kind of change of dimensions under consideration.

Such is an outline of the method by which Rankine deduces

the second law of thermodynamics, or general equation of the mechanical action of heat, from the hypothesis of molecular vortices, by means of known dynamical principles. The quantity whose variation being multiplied by the absolute temperature gives the latent heat, corresponding to a given change of dimensions at that temperature, is expressed in Rankine's earlier papers by symbols, but is not designated by a special name.

In a paper read in January 1853 (Edin. Trans. xxi) he proposes the name *Heat Potential*; and in a paper read to the Royal Society of London, January 1854, he gives to the same quantity, with a certain additional term, depending on changes of temperature, the name of "*Thermodynamic Function*,"—a name which has since been adopted by various other authors.

In Rankine's paper of 1849, the chief applications of the general equation of thermodynamics are as follow:—The values of *apparent* as distinguished from *real specific heat*, for gases and vapours under various circumstances. The demonstration that the apparent specific heat of a vapour kept constantly at the pressure of saturation, while its volume varies, is *negative* for most fluids at ordinary temperature—in other words, that steam, for example, tends to become *partially liquified when it works expansively*, contrary to what had been previously believed. This fact was first verified experimentally by M. Hirn of Colmar. And the demonstration that the total heat of evaporation of a perfect gas increases with temperature at a rate equal to the completed specific heat of the gas at *constant pressure*.

In the paper read December 1850, he deduced from *Joule's Equivalent* the value 0.24 for the specific heat of air, and concluded that the previously received value 0.2669 must be erroneous. This was exactly verified by Regnault's experiments, but not till more than three years afterwards.

In a paper read April 1851 (Edin. Trans. vol. xx. 205) he deduced from the general equation of thermodynamics, as given in his paper of 1849, the following law of the efficiency of a perfect heat engine,—that the *whole heat expended is to the heat which disappears in doing mechanical work, as the absolute temperature at which heat is received to the difference between the temperatures at which it is received and rejected*.

In Rankine's paper of 1849, groups of circular vortices were supposed to be arranged in spherical layers round the atomic nuclei, in order to simplify the investigation. On the 18th December 1851, he read a paper (*Edin. Trans.* xx. p. 425) in which it was shown that precisely the same results as to the relations between heat, elasticity, and mechanical work, follow from the supposition of molecular vortices of any figure arranged in any way. In a long series of papers he applied the principles of thermodynamics to various practical equations relating to the steam-engine and other heat engines, and he was the author of the first separate treatise in which the science of thermodynamics was set forth with a view to its practical application (*A Manual of the Steam-Engine and other Prime Movers*, 1859). In two papers read to the Philosophical Society of Glasgow in 1853-1855 respectively, he pointed out how the laws of thermodynamics and of electrodynamics might be regarded as particular cases of general laws applicable to *energy* in the abstract, and especially to transformation between the two great classes of "actual and potential" energy.

Clausius, who, it is well known, discovered the second law of thermodynamics consentaneously with Rankine, having taken occasion in 1866 to lay great weight on his having adopted no special hypothesis on the molecular constitution of bodies, but to have deduced the second law from general principles, Rankine, in an address to the Philosophical Society of Glasgow, concluded an eloquent justification of the mechanical hypothesis of molecular vortices in these words:—"I wish it to be clearly understood that although I attach great value and importance to sound mechanical hypothesis as means of advancing physical science, I firmly hold that they can never attain the certainty of observed facts; and accordingly, I have laboured assiduously to show that the two laws of thermodynamics are demonstrated as facts independent of any hypothesis; and in treating the practical application of those laws, I have avoided all reference to hypothesis whatsoever."

In March 1854 he was awarded the Keith medal of the Royal Society of Edinburgh for the researches above summarised, mostly in his own words. His name and fame had become European. He was elected Fellow of the Royal Society of London, and con-

tributed to that Society many papers of permanent interest in the course of the next sixteen years.

From January to 20th April 1855, Rankine lectured for Professor Gordon at Glasgow College, on "Applied Mechanics" and the "Application of Thermodynamics to the Theory of the Steam-Engine." These lectures were of so high a character of usefulness, and delivered in so masterly a manner, that steps were immediately taken to get Rankine appointed to the professorship on the resignation of Mr Gordon. The Queen's commission appointing him Regius Professor of Civil Engineering and Mechanics was dated November 7, 1855.

On the 3rd of January 1856 he delivered his introductory lecture "On the Harmony of Theory and Practice in Mechanics," an essay full of practical wisdom. In November 1856 the introductory lecture "On the Science of the Engineer," was delivered, and concludes thus:—"Let the young engineer then be convinced that the profession which he studies is not a mere profitable business, but a liberal and a noble art, tending towards great and good ends, and that to strive to the utmost to perfect himself in that art, and in the sciences on which it depends, is not merely a matter of inclination or of policy, but a sacred duty."

Rankine's whole career as a professor exemplified this view of the profession of an engineer. By efforts, which to ordinary men seem altogether impossible, he published in rapid succession four manuals of "Mechanical and Engineering Science and Practice," on the best models for arrangement, but original in the treatment of many subjects,—always lucid in definition and demonstration, and replete with applications to examples of the practice of experienced men in all departments.

The students of engineering during the previous existence of the Professorship had gradually awakened to the necessity of acquiring some preliminary scientific instruction, and Rankine's style of teaching at once incited them to far higher efforts. It is unquestionable that his scientific works generally, and his manuals of applied science especially, have done more to break down the long persistent fallacy of a discrepancy between rational and applied mechanics, between theory and practice in engineering, than any previous publications whatever, and the influence of his systematic

scientific teaching is spreading true principles of engineering design in this country, as the works of Navier, Poncelet, Morin, and Weisbach had done many years previously on the engineering practice of France and Germany. I say advisedly, that in far fewer cases now-a-days do we see the strength and stability which ought to be given by the skilful arrangement of the parts of the structure, supplied by means of an imposing massiveness involving a lavish expenditure of material and labour—that is, money—than twenty years ago was usual.

His complete knowledge of foreign languages enabled him to correspond with such men as Weisbach, Zeuner, Verdet, and other professors of applied mechanics on the Continent, to the mutual interest and advantage of all. He also corresponded in German with Poggendorf, Clausius, and Helmholtz. Each of the manuals has gone through many editions,—that on the “Steam Engine,” &c., nine; “Applied Mechanics,” seven, and so on.

In 1862 he effectually called the attention of the Senate of the University to the manner in which the usefulness of the Chair of Civil Engineering and Mechanics was impaired through its being isolated from other branches of study, and induced the authorities to establish a systematic curriculum of study and examination in all the sciences bearing on engineering, followed by the granting of certificates to the successful candidates; a measure which led to a steady and continuous increase in the number and efficiency of the students in the engineering department of the University; and it could, indeed, scarcely be otherwise, seeing that William Thomson taught Natural Philosophy, and Rankine taught its applications. His style of lecturing was attractive; he never failed or faltered in an exposition or demonstration; and his power of illustration of the details of steam-engine practice, for example, was unusually lucid from his knowledge of the chemistry of the subject being co-extensive with his mechanical and physical knowledge. He at once gained the confidence of thoughtful students, and during the first session, that in which he lectured for Professor Gordon, he contracted an intimacy with Mr J. R. Napier, a shipbuilder and engineer, ambitious to emancipate his business from being that of one of mere empiricism, and this friendship, as it ripened, proved of great consequence to the whole science of shipbuilding and steam propulsion.

In 1856 he first projected a treatise on shipbuilding, which he ultimately finished in 1866, and published in conjunction with J. R. Napier and others. Of this treatise it may be said it is unique of its kind. It has recently been published in German.

In the autumn of 1857 he contrived a theory of skin resistance of ships, based on experiments furnished by J. R. Napier, and in the next year applied it with complete success to the steam-ship "Admiral," verifying his theory.

The work on shipbuilding occupied much of his spare time. He records at several intervals, from 1863 to 1866, brief notes, such as "Working hard at Treatise on Shipbuilding," "Researches on Neöids," "Stream lines." In 1866 the folio treatise was published. Rankine wrote the greater portion of it, and was the editor. The preparation of this treatise led to a series of researches on fluid motion, which are acknowledged to be of the highest importance, and they certainly belong to the most abstruse parts of mathematical science. Rankine's genius overcame all difficulties, and the "Theory of the Propagation of Waves," the "Theory of Waves near the Surface of Deep Water," and his investigations on plane water lines in two dimensions, *i.e.*, of the lines of motion of water flowing past a ship, advanced, in his hands, the application of science to naval architecture as much as his discovery of the second law of thermodynamics did that of the theory of the steam-engine and other heat engines. For, the practical use of his theory of oögenous water-lines reproduces *known* good forms of water-line, and even reproduces their numerous *varieties*, which differ very much from each other. In fact, there is no form of water-line that has been found to answer in practice which cannot be imitated by means of oögenous neöids—that is, ship-shape curves generated from an oval.

Besides Mr J. R. Napier, the late John Elder was the intimate friend of Rankine, and the bold improvements introduced by that distinguished engineer in marine steam machinery were constantly discussed with Rankine, whose scientific aid in insuring success was gracefully and munificently acknowledged by Elder's widow, by the gift of a large endowment to increase the emoluments of the chair of Civil Engineering and Mechanics.

Rankine's professional business was that of a consulting engi-

neer, and in this capacity he made several reports to his clients of permanent value. One, "On Canal Haulage," is of great interest, and another "On the Explosion of the Tradeston Flour-Mills."

He was consulting engineer of the Highland Society of Scotland.

This sketch of the leading incidents of the scientific works which have made Rankine's name and fame represents, though very feebly, the more permanent portion of his usefulness to his profession and to his generation. But besides these great works, he contributed about 150 papers of greater or less importance to philosophical journals, mechanics' magazines, and to "The Engineer" in particular; generally expositions of such questions as the day or week suggested connected with engineering and mechanics; and it has been truly said—"With him thought was never divorced from work, both were good of their kind; the thought profound and thorough—the work a workmanlike expression of the thought." "Few, if any, practical engineers have contributed so much to abstract science, and in no case has scientific study been applied with more effect to practical engineering."

Rankine was a steady attendant at the meetings of the British Association, and took an active part as President of Section G, or Secretary of Section A, or otherwise in these meetings, where he had a universal acquaintance, and was universally respected and esteemed. He was a member of the "Red Lion's" Club.

In 1857 he took the most active part in founding the "Institution of Engineers in Scotland." He was the first President. It has proved a successful and eminently useful institution.

The outward lustre of Rankine's career is of course derived from his scientific work, but there was an inner halo surrounding him, which to his friends shone even brighter than the outward lustre. He was a true gentleman, gentle, chivalrous, self-forgetting, and scrupulously truthful, a patient listener, a quiet expounder. He supported applause without feeling the weakness of vanity. He had not a vestige of the spirit of rivalry, being of a thoroughly genial temperament. In his judgment of other men he obeyed the pious injunction of Thomas à Kempis, "*Ad hanc estiam pertinet, non quibuslibet hominum verbis credere, nec audita vel credita mox ad aliorum aures effundere.*"

His health for several years in his early youth was feeble, and he

occupied himself much with the theory of music, and practised the piano and violoncello. Though too much occupied in after life to allow of his attaining much proficiency, he could always interest and amuse his friends by singing his own songs to his own music, always gay and cheery. "The Coachman of the Skylark" in 1854, "The Engine-driver's Address to his Engine" in 1858, and "The Mathematician in Love," and "The Three-foot Rule," somewhat later, had a grotesque gracefulness of humour which were irresistible. His appearance was highly prepossessing, as the Fellows of the Royal Society of Edinburgh well know. His social qualities were the admiration of his acquaintances and the delight of his friends. Full of anecdote and information, he was an ornament to society, of which he was always the least obtrusive member, but often the centre of attraction. Everything he did he did well. Singing, croquet, or b  zique, he used to join in them cordially, and intent on the moment's amusement.

His first great grief was the death of his father in May 1870. Rankine's affectionate and devoted nature was deeply moved, and he himself began soon after to experience symptoms of decay of his hitherto vigorous health. When, in April 1871, his excellent mother died, he was for a time quite absorbed by his grief for her loss. His own health became more and more unsatisfactory. Especially his eyesight became very weak, and during 1872 he had to employ an amanuensis and an assistant in his class work, one of his pupils, M. Bamber.

He visited his more intimate friends much during the summer of this year, where he could enjoy rest, and quiet, and amusement. But his health gradually gave way, and towards the end of November his medical friends perceived that the great mind of Rankine was giving way.

On the 24th December he died, leaving a noble record of genius to future generations, and a sweet memory to those of his contemporaries who knew him personally.

3. Obituary Notice of Justus Liebig. By Professor Crum Brown.

JUSTUS LIEBIG was born on the 12th May 1803, at Darmstadt, where his father carried on business as a grocer and colour merchant. He early showed a strong inclination to the study of experimental chemistry, reading all the chemical books he could procure from the Darmstadt Library, and repeating every experiment he read of, as far as he could obtain from his father's warehouse necessary materials. His father acceded to his wish that he should be a chemist, and as the only way in which this could be carried out, sent him at the age of fifteen to an apothecary's shop to learn chemistry. There he remained only ten months, and he returned to Darmstadt satisfied that he must seek some other mode of obtaining his object. He remained at home for some months preparing for a University course, upon which he entered in 1819 at Bonn. He soon left Bonn for Erlangen, where he studied chemistry under Kastner. When at Erlangen he attended Schelling's lectures, and long after used to speak of the interest he had taken in them, and of the injurious effect they had exercised upon his success as a practical investigator. Both at Bonn and at Erlangen he founded a students' society of chemistry and physics, in which the members communicated and discussed novelties of science. Liebig left Erlangen in 1822, having already published a paper on the preparation of Schweinfurth green.

Assisted by the liberality of the Grand Duke Louis of Hesse, he proceeded to Paris, where he attended the lectures of Gay-Lussac, Thenard, and Dulong, and obtained from Gay-Lussac permission to work in his private laboratory. He there carried on his investigation into the composition and properties of the fulminates, the results of which he communicated to the Academy. He at once attracted the notice of Humboldt, who was then resident in Paris, and through his influence was appointed, in 1824, Extraordinary Professor of Chemistry in the University of Giessen. In 1826 he was raised to the ordinary professorship. In 1845 the Grand Duke of Hesse conferred upon him the title of Baron von Liebig. In 1852 he accepted an invitation by the Bavarian Government

to the ordinary Professorship of Chemistry, and the Directorship of the Chemical Laboratory in the University of Munich. He died 18th April 1873, at Munich.

The time had not yet come for a calm and judicial estimate of Liebig's influence on the progress of chemistry. It must be left for future generations of chemists, removed from the direct influence of his work, and unbiassed by personal recollection, to assign him his proper place among the great leaders of chemical thought and investigation. It is, however, possible for us to give a general sketch of his career, and to point out some of the more prominent effects of his work as seen in the present state of the science.

We may consider him as a teacher of chemistry, as an inventor of new means of investigation, as a discoverer of new facts and a creator of new ideas in pure chemistry, and as an expounder of the relations of chemistry to common life and to the arts. As a teacher, he introduced into Germany systematic practical training in laboratory work, and induced the Darmstadt Government to build at Giessen a students' laboratory, which has served as the type of those magnificent scientific laboratories which have recently been erected in connection with all the great German universities. His stinging attacks upon the great German Governments for their neglect of practical scientific education, his own success as a teacher, and the zeal for the good cause which he imparted to his pupils, have had for their effect the establishment throughout Germany of numerous well-equipped and usefully active schools of practical science. It is not too much to say that there is no school of chemistry in the world which does not owe a great part of its usefulness to the example of the Giessen laboratory.

It is unnecessary here to catalogue the improvements in chemical apparatus which we owe to Liebig, but there is one invention which must at once occur to every chemist as of vital importance in the history of the science. Organic analyses were made with great accuracy before 1831, but they could be made only by highly skilled chemists, and involved great labour and trouble. The publication by Liebig, in that year, of his method of organic analyses—the method which (with important but secondary improve-

ments) we still employ, made it easy for any advanced student to make an accurate analysis of an organic body. It may be truly said that the astonishingly rapid development of organic chemistry, which dates from that time, was only rendered possible by the simplification of the method of organic analysis entirely due to Liebig.

Of Liebig's discoveries and speculations it is possible to give, in such a notice as this, only an outline. The whole progress of chemistry for the last fifty years is so intimately connected with what he did, that a life of Liebig would necessarily include the history of chemistry for that period.

His investigations extend to nearly every branch of chemistry, but it was to organic chemistry that he specially devoted himself; and it is through his work, in this direction chiefly, that he has influenced other departments of chemistry and the science generally. His first research, that on fulminic acid, published in Paris in 1823, led to the recognition of the isomerism of fulminic acid and the cyanic acid discovered in 1822 by Wöhler, and was followed by a long series of investigations on the compounds related to cyanogen, in which he opened out and to a great extent explored this intricate and interesting path of inquiry. Another group of researches was directed to the determination of the composition and constitution of organic acids. In a comprehensive memoir published in 1838, he pointed out the analogies between many organic acids and phosphoric acid, and introduced the idea of polybasic acid into organic chemistry, enumerating the criteria for the determination of the basicity of an acid with extraordinary precision and accuracy.

He made numerous analyses of the vegetable alkaloids, and greatly increased our knowledge of their properties, of their equivalents, and of the relation of equivalent to composition.

His investigations into the derivatives of alcohol, particularly those formed by oxidation and by the action of chlorine, including the discovery of aldehyde and chloral, poured a flood of light upon the whole question of the constitution of organic compounds. Liebig was the first to regard ether as an oxide, of which alcohol is the hydrate, and the compound ethers salts. By doing so he challenged the defenders of the "etherine" theory, who looked upon

ether as a hydrate of olefiant gas. The result was one of those controversies which have proved of immense value in the progress of chemistry. In the course of this controversy the relations of alcohol and ether to other substances were investigated and discussed with great minuteness, and the result was the general adoption of Liebig's ethyl theory. The subject of decay, putrefaction, and fermentation early engaged Liebig's attention. Entirely opposed to the *vital* theory of fermentation, he attacked it with both argument and ridicule, and proposed a purely chemical theory, which he defended with great ingenuity.

A very important part of Liebig's work in pure organic chemistry was carried on along with Wöhler. As might be expected, the joint efforts of two men of such genius and industry produced results unexampled in number and importance. One of the first objects of their research (in 1830) was cyanic acid, a substance discovered by Wöhler, and in which Liebig had a special interest from its isomerism with his fulminic acid. But the investigations undertaken by them, which exercised the greatest influence on the science of chemistry were those on the benzoic compounds and on uric acid. These are models of what such work ought to be, not only enriching the science with new facts, but compacting it by the discovery of new relations. The theoretical views brought forward in the papers on benzoic acid and bitter almond oil were the commencement of the development of the new theory of compound radicals which soon took the place of that of Berzelius.

The most widely known part of Liebig's work consists in his applications of chemistry to physiology and agriculture. The facts he discovered in reference to the chemistry of animal and vegetable nutrition, and the explanations he gave of the chemical processes involved in the life of organisms, have had an incalculable effect upon physiological chemistry. In his application of the principles of chemistry to agriculture, he proceeded in a thoroughly scientific manner; and although he in some cases generalised too fast, and was thus led into practical error, his work forms the foundation of a true science of agriculture.

By far the greater part of Liebig's scientific work was done at Giessen. After his removal to Munich, the claims of society and the court life of a capital upon his time made the devotion to

laboratory work which distinguished the earlier part of his career impossible. His work in Munich consisted chiefly in elaborations of his previous ideas, and in researches, the results of which are of comparatively little general scientific interest, although in some cases of considerable practical value. Among these may be mentioned the discovery of the mode of preparing the extract of meat, and that of a method of depositing a uniform coherent layer of silver of any thickness upon smooth surfaces.

Liebig was a most voluminous author. His papers were published in many journals, but chiefly in Poggendorff's "*Annalen*," and in the "*Annalen der Pharmacie*" (now "*Justus Liebig's Annalen der Chemie und Pharmacie*"), of which he became one of the editors in 1831. Of separately published books, the most important are "*Introduction to the Analysis of Organic Bodies*," 1837; "*Chemistry in its Application to Agriculture and Physiology*," 1840; "*Animal Chemistry*," 1842; "*Handbook of Organic Chemistry*" (as second volume of a revised edition of Geiger's "*Pharmacy*"), 1843; "*Chemical Letters*," 1844; "*On the Chemistry of Food*," 1847; "*On Some Causes of the Motions of the Juices in the Animal Body*," 1848; "*Principles of Agricultural Chemistry, with special Reference to the late Researches made in England*," 1855. Of most of these works many editions were published in German and in almost every European language. From 1831 till his death he was one of the editors of the chemical journal now known as "*Justus Liebig's Annalen der Chemie und Pharmacie*." Along with Kopp he edited, from 1847 to 1856, the "*Jahresbericht über die Fortschritte der Chemie*;" and along with Poggendorff and Wöhler, the "*Handwörterbuch der Chemie*."

His personal character was simple and easily characterised. Open, amiable, and generous, vehement in carrying out his convictions, utterly intolerant of pretence and dishonesty, he was either a warm friend or a declared enemy. In controversy he was often violent, sometimes ferocious, but he never struck an unfair blow.

By his death many chemists have lost a friend, and all feel one more link attaching them to the last generation broken.

4. Obituary Notice of Gustav Rose. By Professor Crum Brown.

GUSTAVE ROSE was born in Berlin on the 18th of March 1798. He was the youngest son of the pharmaceutical chemist, Valentin Rose, and the brother of Heinrich Rose, the eminent analytical chemist. He intended to devote himself to mining engineering, and began his practical studies in Silesia; but in consequence of illness gave up this profession, and occupied himself with scientific chemistry and mineralogy. He studied mineralogy under Weiss, in the University of Berlin, and made a large number of careful measurements of crystals. His first published work was his graduation thesis, "*De Sphenis atque Titanitæ systemate Crystallino*," 1820.

Like many young chemists of his time, he was attracted to Stockholm, where he studied under the guidance of Berzelius, the greatest and most accurate chemist of that age, and by frequent excursions in Sweden made himself thoroughly acquainted with the varied mineralogy of that country. In Stockholm he met Mitscherlich, with whom he maintained a life-long friendship. Late in life he felt it necessary for him to explain, which he did in a friendly and modest way, the share he had in the work which led to Mitscherlich's discovery of isomorphism. In 1823 he became lecturer on mineralogy in the University of Berlin; in 1826 he received the title of extraordinary Professor; and in 1849 was appointed ordinary Professor of Mineralogy and Director of the Mineralogical Collections.

Rose travelled much in search of mineralogical knowledge. He visited England, Scotland, Scandinavia, Italy, and France, studying rocks, mines, and museums; and in 1829 was selected by Humboldt as one of his companions in his examination of the Ural and Altai Mountains. There Rose discovered many new minerals, and in a special work, "*Reise nach dem Ural*," 1837 and 1842, made known the remarkable mineral wealth of that part of the Russian empire. His holidays were usually occupied by excursions in Silesia or in the Harz, where he collected the materials for some of his most valuable investigations. During one of his walks in Silesia he sustained an injury of the knee, from which he suffered much, but continued

his lectures till the 11th July 1873, when he was attacked with inflammation of the lungs, from the effects of which he died on the 15th of July.

His most important works were an elaborate memoir on felspar (1823); numerous investigations on quartz, on granite, on the metals which crystallise in rhombohedra; on the conditions under which carbonate of lime crystallises in the form of calcspar, or in that of arragonite, on meteorites, and on the mineralogical constituents of trap-rocks. Besides these purely mineralogical researches, special interest attaches to his study of the relation between the crystalline form and the physical properties of minerals. He pointed out that in tourmaline and in electric calamine the pyro-electric polarity is connected in a constant manner with the crystalline polarity, and described with great minuteness the forms of these minerals.

In 1857 Marbach showed that the crystals of iron pyrites and also those of cobaltine, both minerals crystallising in forms belonging to the regular system, could be divided into two sets, differing extremely in thermo-electric character, the one set more positive than antimony, the other more negative than bismuth. Rose saw at once that this difference must be related to their crystalline form, and that these two sets must possess crystalline characters of a right and left handed kind, and at last succeeded in detecting the difference between them.

Most of his researches were published in "Poggendorff's *Annalen*," in the Transactions of Berlin Royal Academy of Sciences, and in the Journal of the German Geological Society. Besides the "Reise nach dem Ural," already mentioned, he published a short work on the "Elements of Mineralogy," distinguished by beautifully drawn figures, and one on a crystallo-chemical system of classification of minerals.

Professor Rammelsberg, from whose notice of Rose's life most of the foregoing sketch has been taken, testifies to the remarkable kindliness and geniality of his character, to the pleasure which he felt in the success of his young scientific friends, and to his hatred of polemical discussion.

5. Obituary Notice of the Rev. Professor Stevenson, D.D.
By John Small, M.A., Librarian to the University of
Edinburgh.

PROFESSOR WILLIAM STEVENSON was born at Barfod, in the parish of Lochwinnoch, on the 26th October 1805. His father was the proprietor of a small estate called Broadfield, and William was his second son. He entered the University of Glasgow in 1821, and pursued his studies at that University during the usual curriculum in the Faculty of Arts, with the exception of one session (1824-25) which he spent at St Andrews, attracted by the popularity of Dr Chalmers, who was at that time Professor of Moral Philosophy there. While at the University of Glasgow he attended diligently to his studies, and worked particularly for the classes of mathematics and natural philosophy. During the summer months he acted as tutor in the family of the late Mr Cochran of Ladyland, and thus began a friendship which lasted uninterruptedly till the time of his death. It was the arranging and cataloguing the old library at Ladyland that developed the love of books for which he was afterwards so remarkable, and the catalogue he then made is still carefully preserved. He pursued his theological studies at the University of Glasgow, but was in session 1828-29 at the University of Edinburgh. In theology he was a distinguished student, in some sessions carrying off the highest honours. After finishing his university course, he was licensed by the Presbytery of Paisley on the 5th of May 1831.

He officiated for six months in the Presbyterian Church in Limerick in 1832, and in July 1833 was appointed by the Crown assistant and successor to the Rev. George Gleig, minister of Arbroath, on whose death two years afterwards he succeeded to the charge.

While at Arbroath Mr Stevenson enjoyed the friendship of the Rev. Dr Thomas Guthrie, then minister of Arbirlot, and an amusing account is given in the autobiography of that eminent divine, of a public discussion with the Rev. Dr Ritchie, "the Goliath of Voluntarism," held at Arbroath, in which Mr Stevenson took a prominent part (vol. i. p. 167). The account of the discussion on this occasion was published in the form of a pamphlet, with the

following title: "Account of a Meeting held at Arbroath on the 16th April 1834, in Defence of Church Establishments, with a full Report of the Speeches delivered on that occasion by the Rev. Messrs Stevenson, Meek, Whitson, Lee, Guthrie, and Muir." This publication attracted considerable attention, and brought the speakers prominently before the public; one of them was the Rev. Dr Robert Lee, afterwards Professor of Biblical Criticism, then minister of a Chapel-of-Ease at Inverbrothock. In 1839 Mr Stevenson's health gave way, and he suffered so much from chronic bronchitis that he had to spend the winter of that and the following year at Torquay.

On the re-establishment of his health, Mr Stevenson was in 1844 presented by the Crown to the first charge of the parish of South Leith. This valuable preferment enabled him to gratify his intense love of reading, and he collected rare and valuable books, not only on theology, but on every subject illustrating the history and antiquities of Scotland. In 1848 he was elected a Fellow of the Society of Antiquaries of Scotland, and in 1849 he received the degree of D.D. from the University of Edinburgh.

Whilst minister of South Leith Dr Stevenson took much interest in his parochial duties, and in 1851 published a small volume, entitled "Christianity and Drunkenness." He was also a contributor to Macphail's "Edinburgh Magazine," and the topics he handled were "The Buchanites," "Pusey and the Confessional," and matters relating to the great Gorham controversy in the Church of England. He took part in the proceedings of the General Assembly, and was appointed Convener of the Colonial Committee in 1859.

In 1858 he was elected a Fellow of the Royal Society of Edinburgh.

In 1861 he was appointed to the Chair of Divinity and Ecclesiastical History in the University, on the death of the Rev. Dr Robertson. As Professor, his method of conducting the class was somewhat peculiar. In place of giving in each session a simple outline of his very extensive subject, he chose rather to take a limited period in the Church's history, and illustrate this in the most minute manner. Every heresy or controversy that had cropped up in the period selected received due attention, and was

illustrated by extracts from rare works which he had collected for the purpose. In his first session (1861-62), the period embraced in his lectures was only from A.D. 30 to 100.

Although the Government, when he was appointed Professor of Church History, dissociated from the Chair the valuable appointment of Secretary to the Bible Board for Scotland, still Dr Stevenson, from his private resources, was enabled to gratify to the utmost his passion for adding to his library. He was a member of the Bannatyne Club and other literary societies originated for printing valuable historical manuscripts, ancient poetry, &c., &c., and the recondite works he thus received were not in his case put hastily on his shelves, but were carefully read and criticised.

He was Vice-President of the Society of Antiquaries for several years, and, as his colleague, Sir James Simpson, had given a great impetus to archæological matters in Scotland, Dr Stevenson went with him hand in hand. His reminiscences of excursions ("howking expeditions" as they were called) planned by Sir James to places of antiquarian interest in the neighbourhood of Edinburgh, were very amusing.*

As Dr Stevenson, from his excellent scholarship, desired extreme minuteness and accuracy in every literary work, this may account for his published writings being fewer than his abilities led his friends to expect. But, while it was supposed that his appoint-

* One of these, arranged in honour of Dr Reeves, of Trinity College, Dublin, was to inspect the curious buildings still existing at Culross, and Sir James had chartered a steamer to take a large party from Leith to visit that ancient Burgh. So much time, however, had been lost in visiting Inch Garvie and other islets in the Firth, that on reaching Culross, from the shallowness of the water, the steamer had to anchor a long way from the shore. Nothing daunted, Sir James, with a dozen of followers, got into a small boat, but it at last ran aground. The rest of the party getting into another boat, and avoiding the error the first had committed, reached the pier by a circuitous route, and lent their aid to bring the party which had first left the steamer ashore. They were at last carried through the shallow water and mud on the shoulders of the Culross boatmen, and the appearance of Sir James himself as he was supported on the backs of two sailors, with other two lending their assistance, created great merriment. This was often referred to by Dr Stevenson as one of his happiest excursions. Although differing in Church politics, a great friendship existed between Sir James and Dr Stevenson, and on the death of the former Dr Stevenson was much affected. He expressed his feelings in a poem, a portion of which was inserted in the *Life of Sir James* by the Rev. Dr Duns.

ment to the Chair of Church History might have allowed him leisure to publish some results of his extensive reading and matured thought, the plan he had laid down for teaching the history of the Church (as before observed) necessitated the writing of new lectures for each year. In this way he sometimes wrote seventy new lectures in one session. In any intervals of leisure, however, he enjoyed miscellaneous reading, and sometimes indulged in poetical effusions. He translated into verse the Latin rhymes in the well-known Aberdeen Breviary, which he printed, but did not then complete.

As ancient Scottish literature, especially poetry, had always been a favourite subject with him, Dr Stevenson was often consulted about the publication of manuscript remains of our early Doric vernacular, and several works of this kind, when they appeared, were dedicated to him. In 1870 he took much interest in an edition of the works of Gavin Douglas, the poetical Bishop of Dunkeld, then projected. He read over the proof sheets, and aided in expiscating some circumstances attendant on the double consecration of that ancient Scottish Prelate. About the same time he resolved to complete the legends from the Aberdeen Breviary, by appending historical notes, and they at length appeared in an octavo volume about the end of 1872. The title of the work is as follows :—"The Legends and Commemorative Celebrations of St Kentigern, his Friends and Disciples, translated from the Aberdeen Breviary and the Arbuthnot Missal, with an illustrative Appendix. Printed for private circulation, 1872."

In the preface, he states that at one time he had in view "to prepare a complete calendar of the Scottish Saints, and, taking the national legends of the Aberdeen Breviary for a basis, he proposed to intercalate all that he might be able to ascertain regarding those *Dii minores* of our country's earlier faith, who, although not enrolled in that dignified service book, are mentioned in other literary monuments now less recondite than they were then, or have left some dim memories of themselves in the names of the towns, villages, fairs, and wells of our country, sometimes in remote and lonely districts, or spots where there had once been chapels, cells, or hermitages."

The want of leisure prevented his carrying out so extensive a

plan, but we are indebted to him for some interesting information regarding the group of saints more immediately connected with the Lothians and Fife, viz., St Kentigern, and his mother St Thenew (daughter of Loth, King of the Lothians), St Servanus or St Serf, St Columba, St Asaph, St Baldred of the Bass, St Con-wall, and St Palladius.

From his family connection with Clackmannanshire he was much attached to that district, and for several summers he occupied a villa in the neighbourhood of Muckart. In this retirement he was always happy, surrounded by his family, and supplied with the newest literature. One season was distinguished by some rural festivities, which he commemorated in verse in a tiny volume printed in 1872 ("The Yetts o' Muckart; or the Famous Pic-nic and the brilliant Barn-Ball. In hairst auchteen hunder an' seventy-one.")

Finding his health failing, Dr Stevenson, with much reluctance, resigned his Chair in November 1872.

This step was much regretted by his colleagues, and his retirement was gracefully referred to by Principal Sir Alexander Grant, in his opening address of the College, session 1872-73, and in the introductory lectures of his colleagues in the Faculty of Theology, who all expressed the hope that he would enjoy the rest to which he was so well entitled.*

The good wishes of the learned Principal and the Professors were not realised, and the last year of Dr Stevenson's life was spent in much annoyance from the effects of an accident he had

* The allusion by Sir Alexander Grant to Dr Stevenson was in the following terms:—"I regret now to have to announce the retirement, owing to impaired health, of Dr Stevenson, who for eleven years has occupied the important Chair of Divinity and Ecclesiastical History. During that time Professor Stevenson has shown himself to be a man of real learning; he has exhibited that quality which the philosopher Coleridge used to value highly, and which he called 'book-mindedness.' In an age distracted by a number of ephemeral interests, and, at the same time vaunting itself on a Baconian adhesion to things rather than to words, this quality of 'book-mindedness,' the characteristic of the scholar of the olden times, has a tendency to become rare. But, for the interests of humanity, it is necessary that there should be not only men who study nature, but also men whose life is spent in books—whose minds are more taken up with the past than the present; to whom everything suggests an association with some great writer, and who thus

the misfortune to receive some years previously; but, enfeebled as he was, he spent any intervals from suffering in preparing additional notes to his work on *St Kentigern* (which had been very favourably noticed), in the event of an edition being published after his demise. [It is believed that this edition is nearly ready for publication.]

Till within a few days of his death he was able to see his friends, and at last died peaceably on the 14th of June 1873, in the 68th year of his age.

Dr Stevenson was twice married, and left issue by both marriages.

6. Obituary Notice of Auguste De la Rive. By Professor George Forbes.

AUGUSTE DE LA RIVE, one of our foreign Honorary Fellows, was born in the year 1801. He resided principally at Geneva, where for a long time he held a professorial chair. He made journeys in various European countries, and spent a considerable time in England and Scotland. After a long and active life, he was struck down by paralysis. A severe attack of gout added to his infirmity. The death of numbers of his friends and relatives deeply affected him. His state of health rendered it desirable that he should winter in the south of France in 1873. He died at Marseilles on the 27th November 1873, at the age of 72 years. His faculties were not impaired by infirmities, and up to the year of his death he continued to communicate memoirs to the Physical Society of Geneva.

M. De la Rive was chiefly interested in the study of electricity. In the Royal Society catalogue we find 106 articles, chiefly on this

serve as the living interpreters of libraries, and as links to maintain the hereditary succession of thought. Such a man as this is our friend Professor Stevenson, and such a character as his is the appropriate ornament of Universities. He has ever manifested not only the learning, but also the urbanity, of the true scholar; and in quitting the labours of the class-room and the Senate-hall to seek that repose which has now become necessary to him, he will not leave a single enemy behind. He will take with him into privacy the regrets of his colleagues, and their sincere wishes that he may yet enjoy many years of happiness and peace."

subject, written by himself, besides 10 in company with others. Since the date of that catalogue he added to the number. The first paper of importance written by him was published in the year 1822, and contained many ingenious and important experiments illustrative of the discoveries of Oersted and Ampère. His interest in chemistry led him to espouse the chemical theory of the voltaic current. On seven different occasions he supported this view in various scientific journals. His researches on electro-chemical decomposition were in part the basis of the modern art of electro-plating. He made several experimental inquiries into the heat generated by the passage of electricity through conductors; some of his most celebrated and original experiments had reference to the action of magnetism upon the electric discharge. These experiments led him to form a theory of the aurora, on which subject he published a series of articles from the year 1848 to the year 1862. In 1862 he illustrated the theory by a number of beautiful experiments publicly exhibited at Geneva. At various epochs he discussed historically the progress of electrical science.

But the work of M. De la Rive was not confined to electricity. In the years 1838-39 he discussed the phenomenon of sunset, usually called the second coloration of Mont Blanc; and his explanation is now generally adopted. He made experiments on specific heats; and his communications on the variations of terrestrial magnetism, as depending upon elevation above and depression below the surface of the soil, are of considerable value. Some of his latest researches had reference to Faraday's discovery of the magneto-rotary effect of bodies upon plane-polarised light. He was a great friend of Faraday's, of whose life he wrote an interesting review, published in the "*Bibliothèque Universelle*."

Auguste De la Rive exerted himself to spread an interest in science among those with whom he came in contact. His genial manner and his open hospitality gathered round him a large circle of friends. He always extended a helping hand to the young man of science. Many could bear witness to this trait in his character; and it was well illustrated by the manner in which he welcomed Faraday, and discovered his talent, at a time when the coldness of Sir Humphrey Davy would have led many to neglect him.

Most of the scientific societies of Europe bestowed upon M. De

la Rive the title of Honorary Member. The Royal Society of London elected him a Foreign Member. He was also a Corresponding Member of the Academy of Sciences at Paris.

7. Obituary Notice of Dr J. Lindsay Stewart. By Dr Cleghorn, Stravithy.

DR STEWART was a native of Kincardineshire, and obtained his medical education in Glasgow. After graduating he proceeded in 1856 to the Presidency of Bengal as assistant-surgeon; he was present at the siege of Delhi in 1857, and in 1858 he joined the expedition to the Yuzufzai country. In 1860-61 he officiated for Dr W. Jameson as superintendent of the Botanic Garden, Saharunpore. His position gave him an excellent opportunity of becoming acquainted with the vegetation of the Terai and North-West Himalaya, and afterwards at Bijour he studied the Flora of Rohilkund, and of the valleys between the Ganges and Sardah. As Conservator of the Forests of the Punjab (1864), his duties took him to all parts of that province, and also to Sindh, Kashmir, and the inner Himalayan tracts on the Upper Indus, Chenab, and Sutlej rivers, which adjoin Turkistan and Tibet. During his journeys, under the most difficult circumstances, he maintained his habit of taking copious notes, and accumulated an immense store of information regarding the plants of North-West India. The results of these researches are embodied in numerous papers published in the Journals of the Royal Geographical Society, the Asiatic Society of Bengal, the Agri-Horticultural Society of India, and the Transactions of the Botanical Society of Edinburgh. A most interesting account of the vegetation of the extreme north-west corner of the Punjab and the hills beyond it, which he studied during the Yuzufzai campaign, is contained in his "Memoranda on the Peshawur Valley, chiefly regarding its Flora" (*Journ. As. Soc.*, 1863), and in his "Notes on the Flora of Waziristan" (*Journ. Roy. Geo. Soc.*, 1863). In the "Journal of the Agri-Horticultural Society of India" appeared "The Sub-Sevalik Tract, with special reference to the Bijour Forest and its Trees" (vol. xiii. 1865); "Journal of a Botanising Tour in Hazara and Khagan" (vol. xiv. 1866); and "A Tour on the Punjab Salt Range" (vol. i. new series, 1867). His last

communication, "Notes of a Botanical Tour in Ladak or Western Tibet," appeared in the "Transactions of the Botanical Society of Edinburgh" (vol. x. 1869). In 1869, after twelve years of unremitting labour, mental and bodily, Dr Stewart returned to England, and the Government of India entrusted him with the preparation at Kew of a Forest Flora of Northern and Central India. To this great work Dr Stewart devoted a large part of his furlough, and he would doubtless have completed it in a satisfactory manner if his health had not given way. That this was the cause became apparent on his return to India, when, after a few months of office work, sickness obliged him to move from Lahore to the Hill Sanitarium at Dalhousie, where he died on 5th July 1873, aged forty-one.

8. Obituary Notice of John Hunter. By J. T. Bottomly, Esq., The University, Glasgow.

MR JOHN HUNTER was born in Belfast on the 23d of March 1843. He was the only son of the late Dr Hunter of Belfast, a gentleman who, though he was for many years before his death unable to move, was highly esteemed as a consulting physician. Mr Hunter, till he entered Queen's College, Belfast, received his education chiefly at home. During his undergraduate course he was distinguished in nearly every branch of science; and in 1863 he obtained the degree of B.A. in the Queen's University, with first-class honours in Chemistry and Experimental Physics. With similar distinction he took the degree of M.A. the following year. In the interval he held the Senior Scholarship in Chemistry in Belfast, a scholarship which is competed for annually by Bachelors in Arts of the Queen's University; and it was during this year that he published his first paper on the "Absorption of Gases by Charcoal." In 1865 he became assistant to Dr Andrews, the Professor of Chemistry in Queen's College, Belfast, an office which he held till 1870, when he was elected Professor of Mathematics and Natural Philosophy in King's College, Windsor, Nova Scotia. At Windsor his health suffered severely from the climate; and, feeling unable to encounter a second winter, he resigned his professorship, and returned home in the autumn of 1871.

During the winter of that year he took up his residence at Enniscrone, county Mayo, being under medical advice to give up active work for some months at least; but with a strong desire to carry on his chemical researches, he fitted up for himself a temporary laboratory there; and he was actively engaged in prosecuting them at the time of his sudden death, on the 13th of September 1872. His death was occasioned by an acute disease of the brain, of which he seems to have had a slight warning some months previously; but his last illness was not more than a few hours of intense pain.

He was married in 1869. His wife survives him; but he left no children.

Mr Hunter's researches were chiefly concerned with the absorption of gases by charcoal. He examined a large number of charcoals, and came to the conclusion that the greatest absorptive power is possessed by the dense charcoal of the shell of the cocoa-nut. With this material he proceeded to examine the absorption of a very large number of gases and vapours; and he extended his researches to the absorption of mixed vapours. He also investigated the relation between absorption and temperature in the cases of ammonia and cyanogen, and showed that, while raising the temperature at which the charcoal is exposed to, the gas decreases the absorption in both cases; the rate of decrease is much greater in the case of ammonia than in the case of cyanogen, between 0° C. and 55° C.; but at 55° C. the rate of decrease in the case of ammonia suddenly diminishes, and up to 80° C. it is not very much greater than the rate of decrease for cyanogen. At a point a little higher than 55° the volumes absorbed are the same for the two gases. Above this point more of cyanogen gas is absorbed by a given weight of charcoal than of ammonia; but below that point ammonia is enormously more absorbed than cyanogen. Mr Hunter was extending his observations to the effect of pressure on absorption. He had already published two papers on the subject. The last of these was communicated to the Chemical Society of London only a few weeks before his death; and it is in fact scarcely complete, through wanting his final corrections in type on it.

Mr Hunter accompanied the Deep Sea Dredging Expedition in H.M.S. "Porcupine" in the autumn of 1869, and published two

important papers "On the composition of Sea-water collected at different depths of the Atlantic, from a few feet below the surface up to 2090 fathoms," and "On the Composition of the Atlantic Ooze." These analyses included also analysis of the absorbed gases of the water. His papers are all published in the "Journal of the Chemical Society."

He was genial, warm-hearted, affectionate, a universal favourite with those who knew him, enthusiastically devoted to science, and withal highly cultivated in literature and the arts. His premature death, at a time when a life of usefulness seemed to have just commenced, is deeply regretted.

The following statement respecting the Fellows of the Society was submitted:—

I. Honorary Fellows—

Royal Personage,	.	.	.	.	.	1
British Subjects,	.	.	.	.	.	17
Foreign,	.	.	.	.	.	32
Total Honorary Fellows,	.	.	.	.	.	50

II. Non-resident Member under the Old Laws, . . . 1

III. Ordinary Fellows—

Ordinary Fellows at November 1872, . . . 343

<i>New Fellows</i> —William Boyd, Esq.; Donald Crawford, Esq.; Dr John G. M'Kendrick; M. M. Pattison Muir, Esq.; Dr J. Bell Pettigrew; Andrew Pritchard, Esq.; Walter Stewart, Esq.; Robert Tennent, Esq.; Robert Walker, Esq.; Dr Morrison Watson; Robert Wilson, Esq.; Major Welsh,						
	.	.	.	.	.	12
W. Dittmar, Esq., reinstated,	.	.	.	.	.	1
						356
Carried forward,						356

	Brought forward,	356
<i>Deduct Deceased</i> —Rev. Dr Guthrie; Prof. John Hunter; Very Rev. Dean Ramsay; Prof. Macquorn Rankine; Arch. Smith, Esq.; Rev. Prof. Stevenson; Dr J. L. Stewart; R. W. Thomson, Esq.,		8
<i>Resigned</i> —J. F. M Lennan, Esq.; Dr Alex. Wood,		2
<i>Cancelled</i> —Dr Richardson, Dr Foulerton,		2
		12
Total number of Ordinary Fellows at Nov. 1873,		344

The following Communications were read:—

9. The Kinetic Theory of the Dissipation of Energy. By Sir William Thomson.

In abstract dynamics the instantaneous reversal of the motion of every moving particle of a system causes the system to move backwards, each particle of it along its old path, and at the same speed as before, when again in the same position. That is to say, in mathematical language, any solution remains a solution when t is changed into $-t$. In physical dynamics this simple and perfect reversibility fails, on account of forces depending on friction of solids; imperfect fluidity of fluids; imperfect elasticity of solids; inequalities of temperature, and consequent conduction of heat produced by stresses in solids and fluids; imperfect magnetic retentiveness; residual electric polarisation of dielectrics; generation of heat by electric currents induced by motion; diffusion of fluids, solution of solids in fluids, and other chemical changes; and absorption of radiant heat and light. Consideration of these agencies in connection with the all-pervading law of the conservation of energy proved for them by Joule, led me twenty-three years ago to the theory of the dissipation of energy, which I communicated first to the Royal Society of Edinburgh in 1852, in a paper entitled "On a Universal Tendency in Nature to the Dissipation of Mechanical Energy."

The essence of Joule's discovery is the subjection of physical phenomena to dynamical law. If, then, the motion of every par-

ticle of matter in the universe were precisely reversed at any instant, the course of nature would be simply reversed for ever after. The bursting bubble of foam at the foot of a waterfall would reunite and descend into the water; the thermal motions would reconcentrate their energy, and throw the mass up the fall in drops re-forming into a close column of ascending water. Heat which had been generated by the friction of solids and dissipated by conduction, and radiation with absorption, would come again to the place of contact, and throw the moving body back against the force to which it had previously yielded. Boulders would recover from the mud the materials required to rebuild them into their previous jagged forms, and would become reunited to the mountain peak from which they had formerly broken away. And if also the materialistic hypothesis of life were true, living creatures would grow backwards, with conscious knowledge of the future, but no memory of the past, and would become again unborn. But the real phenomena of life infinitely transcend human science, and speculation regarding consequences of their imagined reversal is utterly unprofitable. Far otherwise, however, is it in respect to the reversal of the motions of matter uninfluenced by life, a very elementary consideration of which leads to the full explanation of the theory of dissipation of energy.

To take one of the simplest cases of the dissipation of energy, the conduction of heat through a solid—consider a bar of metal warmer at one end than the other, and left to itself. To avoid all needless complication, of taking loss or gain of heat into account, imagine the bar to be varnished with a substance impermeable to heat. For the sake of definiteness, imagine the bar to be first given with one-half of it at one uniform temperature, and the other half of it at another uniform temperature. Instantly a diffusing of heat commences, and the distribution of temperature becomes continuously less and less unequal, tending to perfect uniformity, but never in any finite time attaining perfectly to this ultimate condition. This process of diffusion could be perfectly prevented by an army of Maxwell's "intelligent demons,"* stationed at the

* The definition of a demon, according to the use of this word by Maxwell, is an intelligent being endowed with free-will and fine enough tactile and perceptive organisation to give him the faculty of observing and influencing individual molecules of matter.

surface, or interface as we may call it with Professor James Thomson, separating the hot from the cold part of the bar. To see precisely how this is to be done, consider rather a gas than a solid, because we have much knowledge regarding the molecular motions of a gas, and little or no knowledge of the molecular motions of a solid. Take a jar with the lower half occupied by cold air or gas, and the upper half occupied with air or gas of the same kind, but at a higher temperature, and let the mouth of the jar be closed by an air-tight lid. If the containing vessel were perfectly impermeable to heat, the diffusion of heat would follow the same law in the gas as in the solid, though in the gas the diffusion of heat takes place chiefly by the diffusion of molecules, each taking its energy with it, and only to a small proportion of its whole amount, by the interchange of energy between molecule and molecule; whereas in the solid there is little or no diffusion of substance, and the diffusion of heat takes place entirely, or almost entirely, through the communication of energy from one molecule to another. Fourier's exquisite mathematical analysis expresses perfectly the statistics of the process of diffusion in each case, whether it be "conduction of heat," as Fourier and his followers have called it, or the diffusion of substance in fluid masses (gaseous or liquid), which Fick showed to be subject to Fourier's formulæ. Now, suppose the weapon of the ideal army to be a club, or, as it were, a molecular cricket bat; and suppose, for convenience, the mass of each demon with his weapon to be several times greater than that of a molecule. Every time he strikes a molecule he is to send it away with the same energy as it had immediately before. Each demon is to keep as nearly as possible to a certain station, making only such excursions from it as the execution of his orders requires. He is to experience no forces except such as result from collisions with molecules, and mutual forces between parts of his own mass, including his weapon. Thus his voluntary movements cannot influence the position of his centre of gravity, otherwise than by producing collision with molecules.

The whole interface between hot and cold is to be divided into small areas, each allotted to a single demon. The duty of each demon is to guard his allotment, turning molecules back, or allowing them to pass through from either side, according to certain

definite orders. First, let the orders be to allow no molecules to pass from either side. The effect will be the same as if the interface were stopped by a barrier impermeable to matter and to heat. The pressure of the gas being, by hypothesis, equal in the hot and cold parts, the resultant momentum taken by each demon from any considerable number of molecules will be zero; and therefore he may so time his strokes that he shall never move to any considerable distance from his station. Now, instead of stopping and turning all the molecules from crossing his allotted area, let each demon permit a hundred molecules chosen arbitrarily to cross it from the hot side; and the same number of molecules, chosen so as to have the same entire amount of energy and the same resultant momentum, to cross the other way from the cold side. Let this be done over and over again within certain small equal consecutive intervals of time, with care that if the specified balance of energy and momentum is not exactly fulfilled in respect to each successive hundred molecules crossing each way, the error will be carried forward, and as nearly as may be corrected, in respect to the next hundred. Thus, a certain perfectly regular diffusion of the gas both ways across the interface goes on, while the original different temperatures on the two sides of the interface are maintained without change.

Suppose, now, that in the original condition the temperature and pressure of the gas are each equal throughout the vessel, and let it be required to disqualify the temperature, but to leave the pressure the same in any two portions A and B of the whole space. Station the army on the interface as previously described. Let the orders now be that each demon is to stop all molecules from crossing his area in either direction except 100 coming from A, arbitrarily chosen to be let pass into B, and a greater number, having among them less energy but equal momentum, to cross from B to A. Let this be repeated over and over again. The temperature in A will be continually diminished and the number of molecules in it continually increased, until there are not in B enough of molecules with small enough velocities to fulfil the condition with reference to permission to pass from B to A. If after that no molecule be allowed to pass the interface in either direction, the final condition will be very great condensation and very low temperature in

A; rarefaction and very high temperature in B; and equal temperature in A and B. The process of disequalisation of temperature and density might be stopped at any time by changing the orders to those previously specified (2), and so permitting a certain degree of diffusion each way across the interface while maintaining a certain uniform difference of temperatures with equality of pressure on the two sides.

If no selective influence, such as that of the ideal "demon," guides individual molecules, the average result of their free motions and collisions must be to equalise the distribution of energy among them in the gross; and after a sufficiently long time, from the supposed initial arrangement, the difference of energy in any two equal volumes, each containing a very great number of molecules, must bear a very small proportion to the whole amount in either; or, more strictly speaking, the probability of the difference of energy exceeding any stated finite proportion of the whole energy in either is very small. Suppose now the temperature to have become thus very approximately equalised at a certain time from the beginning, and let the motion of every particle become instantaneously reversed. Each molecule will retrace its former path, and at the end of a second interval of time, equal to the former, every molecule will be in the same position, and moving with the same velocity, as at the beginning; so that the given initial unequal distribution of temperature will again be found, with only the difference that each particle is moving in the direction reverse to that of its initial motion. This difference will not prevent an instantaneous subsequent commencement of equalisation, which, with entirely different paths for the individual molecules, will go on in the average according to the same law as that which took place immediately after the system was first left to itself.

By merely looking on crowds of molecules, and reckoning their energy in the gross, we could not discover that in the very special case we have just considered the progress was towards a succession of states, in which the distribution of energy deviates more and more from uniformity up to a certain time. The number of molecules being finite, it is clear that small finite deviations from absolute precision in the reversal we have supposed would not

obviate the resulting disequalisation of the distribution of energy. But the greater the number of molecules, the shorter will be the time during which the disequalising will continue; and it is only when we regard the number of molecules as practically infinite that we can regard spontaneous disequalisation as practically impossible. And, in point of fact, if any finite number of perfectly elastic molecules, however great, be given in motion in the interior of a perfectly rigid vessel, and be left for a sufficiently long time undisturbed except by mutual impact and collisions against the sides of the containing vessel, it must happen over and over again that (for example) something more than $\frac{9}{10}$ ths of the whole energy shall be in one-half of the vessel, and less than $\frac{1}{10}$ th of the whole energy in the other half. But if the number of molecules be very great, this will happen enormously less frequently than that something more than $\frac{9}{10}$ ths shall be in one-half, and something less than $\frac{1}{10}$ ths in the other. Taking as unit of time the average interval of free motion between consecutive collisions, it is easily seen that the probability of there being something more than any stated percentage of excess above the half of the energy in one-half of the vessel during the unit of time, from a stated instant, is smaller the greater the dimensions of the vessel and the greater the stated percentage. It is a strange but nevertheless a true conception of the old well-known law of the conduction of heat, to say that it is very improbable that in the course of 1000 years one-half of the bar of iron shall of itself become warmer by a degree than the other half; and that the probability of this happening before 1,000,000 years pass is 1000 times as great as that it will happen in the course of 1000 years, and that it certainly will happen in the course of some very long time. But let it be remembered that we have supposed the bar to be covered with an impermeable varnish. Do away with this impossible ideal, and believe the number of molecules in the universe to be infinite; then we may say one-half of the bar will never become warmer than the other, except by the agency of external sources of heat or cold. This one instance suffices to explain the philosophy of the foundation on which the theory of the dissipation of energy rests.

Take however another case, in which the probability may be

readily calculated. Let a hermetically sealed glass jar of air contain 2,000,000,000,000 molecules of oxygen, and 8,000,000,000,000 molecules of nitrogen. If examined any time in the infinitely distant future, what is the number of chances against one that all the molecules of oxygen and none of nitrogen shall be found in one stated part of the vessel equal in volume to $\frac{1}{10}$ th of the whole? The number expressing the answer in the Arabic notation has about 2,173,220,000,000 of places of whole numbers. On the other hand, the chance against their being exactly $\frac{2}{10}$ ths of the whole number of particles of nitrogen, and at the same time exactly $\frac{2}{10}$ ths of the whole number of particles of oxygen in the first specified part of the vessel, is only 4021×10^9 to 1.

APPENDIX.

Calculation of probability respecting Diffusion of Gases.

For simplicity, I suppose the sphere of action of each molecule to be infinitely small in comparison with its average distance from its nearest neighbour; thus, the sum of the volumes of the spheres of action of all the molecules will be infinitely small in proportion to the whole volume of the containing vessel. For brevity, space external to the sphere of action of every molecule will be called free space: and a molecule will be said to be in free space at any time when its sphere of action is wholly in free space; that is to say, when its sphere of action does not overlap the sphere of action of any other molecule. Let A, B, denote any two particular portions of the whole containing vessel, and let a , b , be the volumes of those portions. The chance that at any instant one individual molecule of whichever gas shall be in A is $\frac{a}{a+b}$, however many or few other molecules there may be in A at the same time; because its chances of being in any specified portions of free space are proportional to their volumes; and, according to our supposition, even if all the other molecules were in A, the volume of free space in it would not be sensibly diminished by their presence. The chance that of n molecules in the whole

space there shall be i stated individuals in A, and that the other $n - i$ molecules shall be at the same time in B, is

$$\left(\frac{a}{a+b}\right)^i \left(\frac{b}{a+b}\right)^{n-i}, \text{ or } \frac{a^i b^{n-i}}{(a+b)^n}.$$

Hence the probability of the number of molecules in A being exactly i , and in B exactly $n-i$, irrespectively of individuals, is a fraction having for denominator $(a+b)^n$, and for numerator the term involving $a^i b^{n-i}$ in the expansion of this binomial; that is to say, it is—

$$\frac{n(n-1)\dots(n-i+1)}{1.2\dots i} \left(\frac{a}{a+b}\right)^i \left(\frac{b}{a+b}\right)^{n-i}.$$

If we call this T_i , we have

$$T_{i+1} = \frac{n-i}{i+1} \frac{a}{b} T_i.$$

Hence T_i is the greatest term if i is the smallest integer, which makes

$$\frac{n-i}{i+1} < \frac{b}{a};$$

this is to say, if i is the smallest integer which exceeds

$$n \frac{a}{a+b} - \frac{b}{a+b}.$$

Hence if a and b are commensurable, the greatest term is that for which

$$i = n \frac{a}{a+b}.$$

To apply these results to the cases considered in the preceding article, put in the first place

$$n = 2 \times 10^{12},$$

this being the number of particles of oxygen; and let $i = n$. Thus, for the probability that all the particles of oxygen shall be in A, we find

$$\left(\frac{a}{a+b}\right)^{8 \times 10^{12}}.$$

Similarly, for the probability that all the particles of nitrogen are in the space B, we find

$$\left(\frac{b}{a+b}\right)^{2 \times 10^{12}}.$$

Hence the probability that all the oxygen is in A and all the nitrogen in B is

$$\left(\frac{a}{a+b}\right)^{2 \times 10^{12}} \times \left(\frac{b}{a+b}\right)^{2 \times 10^{12}}.$$

Now by hypothesis

$$\frac{a}{a+b} = \frac{2}{10},$$

and therefore

$$\frac{b}{a+b} = \frac{8}{10};$$

hence the required probability is

$$\frac{2^{26 \times 10^{12}}}{10^{10^{13}}}.$$

Call this $\frac{1}{N}$, and let $\log$ denote common logarithm. We have $\log N = 10^{13} - 26 \times 10^{12} \times \log 2 = (10 - 26 \log 2) \times 10^{13} = 2173220 \times 10^6$. This is equivalent to the result stated in the text above. The logarithm of so great a number, unless given to more than thirteen significant places, cannot indicate more than the number of places of whole numbers in answer to the proposed question, expressed according to the Arabic notation.

The calculation of T_i , when i and $n-i$ are very large numbers, is practicable by Stirling's theorem, according to which we have approximately

$$1.2 \dots i = i^{i+\frac{1}{2}} e^{-i} \sqrt{2\pi},$$

and therefore

$$\frac{n(n-1) \dots (n-i+1)}{1.2 \dots i} = \frac{n^{n+\frac{1}{2}}}{\sqrt{2\pi} i^{i+\frac{1}{2}} (n-i)^{n-i+\frac{1}{2}}}.$$

Hence for the case

$$i = n \frac{a}{a + b},$$

which, according to the preceding formulæ, gives T_i its greatest value, we have

$$T_i = \frac{1}{\sqrt{2\pi nef}},$$

where

$$e = \frac{a}{a + b} \text{ and } f = \frac{b}{a + b}.$$

Thus, for example, let $n = 2 \times 10^{12}$;

$$e = .2, f = .8,$$

we have

$$T_i = \frac{1}{800000 \sqrt{\pi}} = \frac{1}{1418000}.$$

This expresses the chance of there being 4×10^{11} molecules of oxygen in A, and 16×10^{11} in B. Just half this fraction expresses the probability that the molecules of nitrogen are distributed in exactly the same proportion between A and B, because the number of molecules of nitrogen is four times greater than of oxygen.

If n denote the molecules of one gas, and n' that of the molecules of another, the probability that each shall be distributed between A and B in the exact proportion of the volume, is

$$\frac{1}{2\pi ef \sqrt{nn'}}.$$

The value for the supposed case of oxygen and nitrogen is

$$\frac{1}{2\pi \times .16 \times 4 \times 10^{12}} = \frac{1}{4021 \times 10^9},$$

which is the result stated at the conclusion of the text above.

10. On the Stresses due to Compound Strains. By Prof. C. Niven. Communicated by Prof. Tait.

(*Abstract.*)

In the treatment of questions which relate to the equilibrium vibrations of elastic solids, it is usual to suppose the substance to start from a state without strain, and in general to consider only the case of small distortions, for which squares and products of the space-variations of displacement may be neglected. The mathematical solution depends, in the first instance, on the expression of the work done in distorting an element. This, as was first done by Green, is expressed in terms of six functions of the distortions, termed strains. The part of the potential function which is of the second degree contains 21 coefficients, reducible to 18 by a proper choice of axes. But in the present state of our knowledge of the constitution of æolotropic substances, it is in general impossible to effect a further reduction, and it is probable that the function will have different forms according to the previous history of the substance.

The case in which the æolotropy has been produced by the action of considerable stress has formed the subject of investigations by Cauchy, St Venant, and others. Cauchy's results were based directly on the consideration of molecular attractions; and though the other authors have employed Green's theory of the potential energy, they have still made use of molecules to find its form.

In the present paper the author has sought to base the treatment of the subject on the law of superposition of one set of strains on another. If these states of strain be called respectively primary and secondary, it is shown that the total strains differ from the primary by linear functions of the secondary, and this whether the latter be small or large. The true form of the potential in terms of the secondary strains is thereafter readily found. It agrees so far with the result of M. Boussinesq, and furnishes expressions for the stresses agreeing to a certain extent with those originally given by Cauchy.

There is one part of the potential energy due to the secondary strains which has not hitherto been discussed. It consists of terms

due to parts in the primary potential, which are respectively of the degrees 2, 3, 4 . . . in the strains. The first of these has been completely investigated in the present paper, and the potential is shown to depend on two invariants which are functions of the secondary strains, and of six quantities called the primary quasi-strains. In fact, borrowing a term from the theory of reciprocal surfaces, we may say shortly that the part of the potential energy under consideration is $\frac{1}{2} \left(\frac{m J_1^2}{4} + n J_2 \right)$, where J_1 is the invariant of the first order of the secondary strains and primary quasi-strains, and $-J_2$ is the corresponding invariant for the reciprocals of these systems.

It is also shown in the present paper that these quasi-strains play an important part in the elasticity of isotropic solids; for besides the above result, it appears that, with the limitation of the potential already mentioned, the products of the stresses into the strained element-volume are directly expressible in terms of them, and that the principal axes of stress coincide with those of quasi-strains. The present paper also contains the equations which express the small motions of a strained solid, with the view of testing whether they present any analogy with the luminous waves. The results are negative, as was to be expected, there being in glass three real waves for every direction of the wave-front, and the wave surface being of the sixth class. In the case where the primary stress is symmetrical round an axis, an ellipsoid of revolution detaches itself from the general surface.

Among other subsidiary results of this paper may be mentioned the derivation (from the law of superposition of strains) of the symbolical expressions for the stresses in terms of the strain-variations of the potential energy (already found in another shape by M. Boussinesq), and the symbolized solution of the converse problem.

The law of resolution of strains and quasi-strains has been shown to be identical with that of stresses and with various other mathematical magnitudes, among which may be mentioned the system consisting of the moments and negative products of inertia of a solid body. A general view of this law of resolution of stresses is given and coupled with a parallel view of forces, along with a

general method of deducing the corresponding invariants and the derived stress- and force-functions. It enables us to see at a glance the meaning of the form found for the potential energy in the secondary strain. The author may be allowed to add, that these methods have been since developed with the view of applying them to the problem of the elasticity of crystals, and that the results obtained, though dual in form, exhibit a striking coincidence with these now given.

